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TASK CLUSTERING METHODOLOGY COMPARISON

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SUMMARY

Increasingly complex weapon systems, demographic fluctuations, competition from other branches of the military and private industry all point to difficult and exciting times for the training analysts and policy makers. To have an effective and efficient workforce, the best technologies need to be used for training. Before the training may begin, however, certain decisions must be made concerning who, what, when, where, why, and how the jobs are to be trained. This is critical if restricted funds are to be used wisely and necessary skills transmitted to personnel as these skills are needed. Clustering tasks into logical groups which should be trained together is one type of decision that may greatly assist in this process. This paper examines two methods of grouping tasks. One method is the product of the Training Decisions System (TDS) research and development project at the Air Force Human Resources Laboratory, Training Systems Division (AFHRL/ID). The other is the method previously used regularly in the training development process by the USAF Occupational Measurement Center, Training Development Services Division (USAFOMC/OMT). Several general comparisons are presented in a question and answer format for those issues which do not change regardless of the Air Force specialty (AFS) being examined. Specific comparisons are presented for the Heating System Specialist (AFSC 545X2) and Security Police Specialist (AFSC 811XX). The TDS method, which is a combination of quantitative and qualitative techniques, was found to have several advantages over the OMT method, which is essentially qualitative. The TDS method takes much less time, takes advantage of statistical clustering techniques, includes the same potential for training analyst input, and requires the same amount of input from subject-matter experts (SMEs) in the field.

PREFACE

The Training Decisions System (TDS) research and development (R&D) program was sponsored by the Headquarters of the United States Air Force (HQ USAF/DPPE) and the Air Force Training Command (HQ ATC/XPCR). The TDS R&D program involved the development of an interactive computer based training decisions aid for training management programming and planning. One of the most important aspects of the system is clustering tasks together for training purposes. The present effort compares the new TDS task clustering methodology with an existing task clustering methodology. This effort required considerable cooperation and assistance from many people. Dr. Lamb, who now works in the Training Systems Division of the Air Force Human Resources Laboratory, performed this work while employed at Universal Energy Systems, Inc. Special recognition goes to Mr. Wayne Archer and Mr. Bill Phalen of the Manpower and Personnel Division for their contributions in developing Appendix A. In addition, we thank Major James Mika and Ms. Cindy White of the USAF Occupational Measurement Center, Training Development Services Division (USAFOMC/OMT), for their assistance to the contractor and for their review of the draft publication and Mr. Ralph Lindeman of Universal Energy Systems, Inc., for accomplishing the data input. Finally, special thanks go to Technical Sergeants Randy J. Dollinger, Robert D. Dunn, Lyle D. Hopkins, and John J. Hamlin, Jr., subject matter experts from Sheppard Air Force Base, Texas, for their help in constructing the final Task Training Modules.

TABLE OF CONTENTS

I.	INTRODUCTION.....	1
II.	THE TRAINING DECISIONS SYSTEM (TDS) CLUSTERING TECHNIQUE.....	2
	Phase I: Statistical Clustering.....	2
	Phase II: Cluster Diagram Interpretation.....	3
	Phase III: SME Cluster Refinement Workshops.....	3
III.	THE OMT CLUSTERING TECHNIQUE.....	4
	Phase I: Initial Clustering.....	4
	Phase II: SME Workshops.....	4
	Phase III: Training Sequence Clustering.....	5
IV.	GENERAL POINTS OF COMPARISON.....	6
V.	SPECIFIC POINTS OF COMPARISON.....	7
	The Heating System Specialist (AFSC 545X2) Comparison.....	8
	The Security Police Specialist (AFSC 811XX) Comparison.....	10
VI.	CONCLUSIONS AND FUTURE RESEARCH CONSIDERATIONS.....	13
	Conclusions.....	13
	Future Research Considerations.....	14
	OSR Task List Audit.....	14
	Task Training Bundles.....	15
	Additional Clustering Variables.....	15
	SME Workshop Enhancement.....	16
	Additional SME Input.....	17
	Additional Comparisons.....	17
	REFERENCES.....	19
	Appendix A: The TDS co-performance clustering process.....	21
	Appendix B: TDS Preliminary Clusters (TTMS) - AFS 545X2 (Heating System Specialist).....	30
	Appendix C: TDS Final Clusters (TTMs) - AFS 545X2 (Heating System Specialist).....	51
	Appendix D: OMT Preliminary Clusters (TMs) - AFS 545X2 (Heating System Specialist).....	69

LIST OF FIGURES

<u>FIGURE</u>		<u>PAGE</u>
1	AFS 5452X2 - Heating System Specialist TDS and OMT Comparison.....	9
2	AFS 811XX - Security Police Specialist TDS and OMT Comparison.....	12
3	Bases for Additional Comparisons.....	18
A-1	Format of a Job Inventory.....	21
A-2	Example of a Case-Oriented Data File from a Job Inventory.....	22
A-3	A Task-Oriented Data File	23
A-4	Beginning Similarity Matrix	24
A-5	Stage 3 Similarity Matrix	25
A-6	Stage 2 Similarity Matrix	26
A-7	Stage 1 Similarity Matrix	27
A-8	A Section of a Diagram Produced by the CODAP DIAGRAM Program	28
A-9	Interpretation of the Contents of a Diagram Data Block	28
A-10	Section of the PRTFAC Report Produced for AFS 545X2	29

TASK CLUSTERING METHODOLOGY COMPARISON

I. INTRODUCTION

The Air Force has a need to establish consistency, logic, and rigor in the training decision making, programming and planning process. The weapon systems now being developed are more complex, the support equipment is more complex, and the occupational categories which are created to perform the required work are becoming more complex and demanding. As a result, support specialties required to enable the maintenance and operational communities to function effectively are undergoing rapid changes.

The dynamic state of the workforce requires flexible methods for providing information and evaluating decisions which impact the training of these specialties. The Training Decisions System (TDS) developed by the Air Force Human Resources Laboratory (AFHRL) is such a method. The TDS is a system which integrates several subsystems to allow analysts to investigate training planning and programming options. The four subsystems in the TDS are the Task Characteristics Subsystem (TCS), the Field Utilization Subsystem (FUS), the Resource/Cost Subsystem (RCS), and the Integration and Optimization Subsystem (IOS). The Task Characteristics Subsystem includes a set of procedures for clustering tasks into Task Training Modules (TTMs) (Collins, Hernandez, Ruck, Vaughan, Mitchell, and Rueter, 1987).

The United States Air Force Occupational Measurement Center Training Development Services Division (USAFOMC/OMT) also performs task clustering but uses somewhat different procedures. The OMT clustering method (hereafter referred to as the OMT method) provides "the data needed by training planners or managers to make decisions about training programs and by training developers to design instructional systems and create training materials" (USAFOMC, 1987). Since the completion of this study, USAFOMC/OMT has implemented new procedures in their training development process. Therefore, this paper reflects the findings resulting from a comparison of the two clustering methodologies prior to the implementation of the new OMT procedures.

Both of these clustering methodologies -- the TDS and the OMT-- group tasks together to best utilize training resources and make training planning, management, and program decisions. The grouping techniques used, called "clustering" methods, vary in subtle but distinct ways. More specifically, the TDS clusters tasks to form the most basic units of analysis for an interactive computer system to allow simulation and modeling of training decisions. OMT clusters tasks to ease task analysis, a vital step in training development. The goal of this paper, therefore, is to compare and evaluate only the clustering methods.

The paper includes a brief presentation of the TDS and OMT clustering methods and then continues with a comparison of the two techniques. The scope of the comparison included both general comparisons and more specific comparisons. The general comparisons deal with the TDS and OMT process as a whole, and hold true regardless of which Air Force specialty (AFS) is being examined. There also are several specific comparisons between the TDS and OMT methods when applied to the Heating System Specialist (AFSC 545X2) and the Security Police Specialist (AFSC 811XX) AFSs. This comparison is followed by a section outlining conclusions and future research considerations.

II. THE TRAINING DECISIONS SYSTEM CLUSTERING TECHNIQUE

The TDS clustering technique is composed of three phases: (a) statistical clustering, (b) cluster diagram interpretation, and (c) Subject Matter Expert cluster refinement workshops. Each of these phases will be addressed briefly.

Phase I: Statistical Clustering

The probability of co-performance is the basis for clustering the tasks together in TDS. The clustering is performed using the statistical routines found in the Comprehensive Occupational Data Analysis Programs (CODAP). The co-performance of tasks is defined as tasks which "are done by the same group of people, although not necessarily at the same time" (Collins et al., 1987:p.9). About tasks clustered into TTMs on the basis of co-performance, it can be said that "if an airman performs one task in the group, it is likely that he/she also performs others in the same group" (Perrin, Vaughan, Yadrick, Mitchell, & Knight, 1986, pp. 11-12). Perrin, Vaughan et al. (1986) present more detail on the entire TDS clustering technique.

Previous research on validating the TDS clustering procedures through task analysis of the knowledges and skills represented in the TTMs found that "the tasks within a TTM were more similar than tasks from different TTMs" (Perrin, Mitchell, & Knight, 1986, p. 17). That is, the tasks within a TTM reveal a common set of skill and knowledge requirements underlying all TTM component tasks but are not redundant with those skill and knowledge requirements of another TTM.

TDS uses a hierarchical clustering technique in CODAP called the average linkage clustering procedure. This is a well-accepted procedure that has been validated in several empirical studies (Milligan, 1981; Mojena, 1977). The procedure provides a measure of group similarity called average overlap "between" groups and a measure of group homogeneity called average overlap "within" a group. The measures are calculated from values in an overlap matrix

constructed from inputs of survey respondents who perform the tasks. A more thorough explanation of these measures is presented by Archer (1966). Appendix A of the present report provides a step-by-step explanation of the TDS co-performance task clustering process.

Phase II: Cluster Diagram Interpretation

After an initial clustering diagram is produced, the job analyst examines the clusters of tasks and makes judgments as to which groups are the best-matched pairs. These judgments include assessment of similarity of skill and knowledge requirements, commonality of equipment, and other characteristics. The large graphics display produced by the CODAP DIAGRM program is the primary tool for analysis. The "data blocks" are printed out in the clustering diagram and are linked by lines which connect them to other data blocks (the next clustering stage). The data blocks are composed of several pieces of information about the cluster which the blocks represent:

1. The clustering stage
2. The number of tasks in the cluster
3. The TPATH range
4. The average percentage overlap "between" and
5. The average percentage overlap "within."

A section of a cluster diagram is shown in Figure A-8, and interpretation of the contents of a data block is shown in Figure A-9. The rule of thumb which has evolved in the use of the diagram by analysts is that the average percentage overlap between two groups that merge should be no less than 33% (Perrin, et al., 1986).

In addition to the diagram, the CODAP clustering procedure provides the analyst with a PRTFAC, a listing of the tasks sorted in clustering sequence or "TPATH." Other data on the PRTFAC include the task duty type, number, and title as they appear in the job inventory survey. Although it is not part of the CODAP clustering programs, the PRTFAC is a vital document for diagram interpretation (see Figure A-10). The Specialty Training Standards (STSS) and Career Development Courses (CDCs) for an AFS also are consulted when the analyst is uncertain about a cluster. The analyst also may access information such as test and support equipment used, skill and knowledge requirements, task difficulty, and percent members performing, to evaluate the clusters.

Phase III: SME Cluster Refinement Workshops

Once an initial set of task clusters have been selected based on the statistical cluster analysis, the clusters are refined by subject matter experts.

The analyst then arranges for group meetings of SMEs in the AFS under study to review and refine the clusters. The SMEs are asked to discuss the clusters for the following purposes:

1. To name the clusters (TTMs)
2. To reassign incorrectly clustered tasks
3. To group single tasks
4. To group clusters together and
5. To create new clusters.

The analyst plays a relatively passive role in the workshop, functioning primarily as a provider of information and answering questions. The SMEs record their results and direct their own discussions.

III. THE OMT CLUSTERING TECHNIQUE

The OMT clustering technique is intended to produce groups of tasks which should be trained together. Given these groups (clusters), the analysts are able to judge where the tasks should be trained (Resident School, Field Training Detachment, or On the Job) and when they should be trained during an airman's career.

The OMT clustering process is quite flexible and utilizes judgments of analysts as well as SMEs. There are three phases to the OMT clustering process: (1) the initial clustering, (2) the SME workshops, and (3) the training sequence clustering. Each phase is addressed briefly.

Phase I: Initial Clustering

In this phase, the analyst uses several criteria to cluster the tasks into initial working clusters or Training Modules (TMs). In particular, the analyst examines similarities in the equipment system involved, in the functional area involved, in the location of task accomplishment, and in the assignment level of the task. These tasks come from sources such as Occupational Survey Reports (OSR), AFR 39-1 and Technical Orders (TOs). The practicalities of temporary duty (TDY) travel to interview SMEs who perform the tasks in Phase II are also a factor taken into consideration in Phase I. Minimizing travel to save money is important; therefore, local SMEs are interviewed first. The clusters which result from this effort are then subject to revision in Phase II.

Phase II: SME Workshops

In this phase, the analysts take the initial clusters created in Phase I to field workshops for examination by SMEs

and for gathering additional task analysis data. These workshops may be conducted one-on-one or with groups of SMEs. The SMEs are asked to examine the clusters of tasks and modify the clusters by adding or deleting tasks or creating new clusters if needed. In comparison to TDS, there is considerably more active involvement of the analyst in the OMT workshops. Also, emphasis is placed on action verbs: that is, "Tasks that can be clustered generally have the same action verb, e.g., 'inspect' or 'calibrate' and they will have common activities, skills, and knowledges" (USAFOMC, 1986, p. 62). During the workshop, it is often found that the Occupational Survey Report (OSR) task list is incomplete and therefore new tasks are added. Similarly, tasks no longer performed because of changes in equipment may be eliminated. Also, changes in policies within the command or organization may dictate that tasks be performed in a way that eliminates subtasks or sequences of tasks. The clusters which result from this effort are then submitted to analysis in Phase III.

Phase III: Training Sequence Clustering

In this phase, clustering of the tasks may be accomplished by the method used during task analysis, by the type and/or level of training recommended, or both. The primary aim of this phase is to sequence the tasks for training purposes. There are several factors used to determine the sequence in which training requirements should be addressed. These factors are presented in order of precedence:

Dependency - A task depends on the knowledge and skills presented in an earlier lesson.

Work Sequence - Training requirements are presented in the order of the performance of the tasks on the job.

Functional Grouping - Tasks which relate to similar hardware or procedures are presented together to maximize transfer of training.

Ease of Learning - Easier training requirements are presented before more difficult ones.

Spatial Orientation - Instruction is sequenced from one end of a piece of equipment to the other.

Training requirements can normally be clustered into groups which are relatively independent of each other. If this is the case, tasks within the clusters may be sequenced according to the estimated difficulty of learning the material in each (easier first, building toward the most difficult). An additional benefit can be developed in this clustering

process: resource efficiencies. For example, in developing a self-paced program, some resource efficiencies may be achieved by having a student's progression through independent clusters based on resource availability. That is, the progression within a cluster of related tasks may be fixed in accordance with the principles identified above, while progression from one cluster to another is based on the availability of equipment or other needed resources. Of course, all students will have to complete all clusters in their course (USAFOMC, 1986, pp. 97-98). Consequently, a training program that addresses training requirements plus resource availabilities can be developed.

IV. GENERAL POINTS OF COMPARISON

There are a number of very basic but quite important general points of comparison between the two methods which are independent of the specialty being examined. These points will be addressed in question-and-answer format.

1. Are the reasons for or the intent of the clustering the same?

Yes. Both methods have as their goal the grouping together of tasks to assist in training planning, programming, development, and resource utilization.

2. Are the units of analysis the same?

Yes. A task is defined the same in both methods; that is, both use (OSR) tasks as the basic clustering units. In both methods, the initial task lists are those found in the current OSR for the AFS under investigation.

3. Are the clustering variables the same?

Yes and no. In general, the answer is "yes"; however, the variables are included in the analysis at different times in slightly different ways. In addition, the TDS uses the co-performance variable, which does not occur in the OMT method. In the first phase of the TDS clustering process co-performance is used to group tasks statistically. Later, in interpreting the cluster diagram and in the cluster validation workshop, numerous other variables including those used in the OMT method may be used by the analyst or by the SMEs in the field. In the various phases of the OMT method, a variety of variables may be used. Some of those variables include conditions, standards, skills and knowledges, subtasks, percent members performing, training emphasis, task difficulty and variables relevant to determining training sequence.

4. Is the clustering process the same?

No. This is a major point of difference between the two clustering methods. The TDS method combines quantitative and qualitative methods, i.e., statistical clustering, occupational analyst interpretation, and SME refinement. The OMT method relies solely on qualitative methods, i.e., with occupational analyst clustering and SME refinement. Both the OMT and TDS methods use analyst and SME inputs but the TDS method adds the extra dimensions of statistical clustering into the overall clustering methodology.

The advantages of working with the SMEs in the field -- current data on tasks actually performed or not performed, policies which change some tasks, definition of subtasks, new tasks added -- may be exploited with either method. Some of the activities which presently take place in the OMT SME workshops do not take place in the TDS SME workshops, but these activities certainly may be included at the analyst's discretion.

5. Are the types of cluster validation used the same?

Yes. Both the TDS and the OMT methods use SME workshops to validate the initial clusters.

6. Are the times for completion the same?

No. This is another major point of difference between the two methods. Phases I and II of the TDS clustering procedure usually take less than 5 workdays, depending on the length of the task list and computer downtime. A lengthy task list, and computer availability problems, may extend Phase I and Phase II to 10 working days. The SME workshops, once arrangements have been made, normally will involve four to five SMEs for 1 day. It is quite conceivable that the whole TDS clustering process could be accomplished in less than 4 weeks for one AFS. The OMT procedure requires more time, due to continued refinement of the clusters during the task analysis phase of training development. Therefore, depending on the complexity of the AFS the OMT process can take up to 6 months to accomplish.

V. SPECIFIC POINTS OF COMPARISON

There are several specific points of comparison which focus on the cluster solutions that are determined by using the two methods. The present investigation compared the methods with data from two specialties: the Heating System Specialist (AFSC 545X2) and the Security Police Specialist (AFSC 811XX).

The Heating System Specialist Comparison

There were 453 Heating System Specialist tasks used in this study. All A, B, and C duty indicator tasks were eliminated as nontechnical tasks common to most specialties. In this comparison, the TDS Preliminary and TDS Final TTM cluster solutions were compared to the OMT Preliminary TM solution. The TDS Final TTMs were produced as a result of the SME Workshops at Sheppard AFB, Texas. The OMT Preliminary TMs were provided at the contract kickoff meeting in October 1987. The OMT Preliminary TMs were used because the final TMs were not yet available.

Appendix B includes a list of the TDS Preliminary TTMs and the number of tasks in each, as well as a listing of the tasks in each Preliminary TTM. Appendix C includes a list of the TDS Final TTMs, the number of tasks in each, the title given to each TTM by the SMEs, and a listing of the tasks in each Final TTM. Appendix D includes a list of the OMT Preliminary TMs, their titles, and a listing of the tasks in each TM. The results of the clustering process are summarized in Figure 1. In the TDS Preliminary phase, there were 46 clusters, with an average size of 9.85 tasks. The smallest was 1 unclustered task (K-286, arc weld lines, bracings, or fittings) and the largest had 48 tasks. Twenty-six (26) of the 46 clusters or 57% had 5 or fewer tasks. In the TDS Final phase, there were 17 clusters with an average size of 26.64 tasks. The smallest was 1 unclustered task (K-309, remove asbestos insulation on ducts or pipes) and the largest had 76 tasks. Only 3 of the 17 clusters or 18% had 5 or less tasks. In the OMT Preliminary phase, there were 20 clusters, with an average size of 22.65 tasks. The smallest was 1 unclustered task (G-195, measure and cut pre-formed insulation) and the largest had 67 tasks. Three (3) of the 20 clusters or 15% had 5 or fewer tasks.

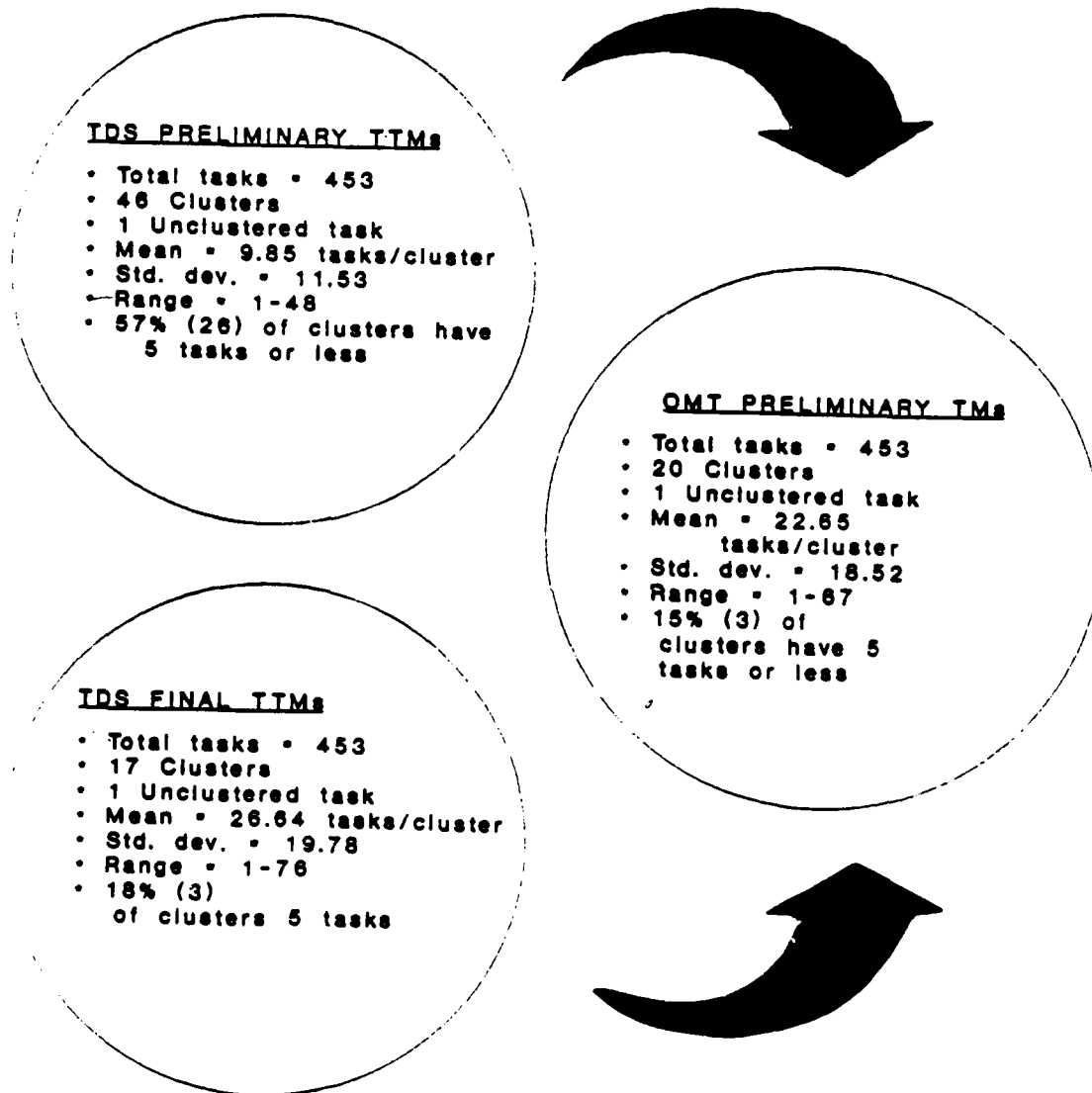


Figure 1. AFS 545X2 - Heating System Specialist TDS and OMT Cluster Comparison.

It should be noted that after the SME inputs the number of TTM clusters was reduced from 46 (with an average of 9.85 tasks) to 17 (with an average of 26.64 tasks), indicating that the data capturing associated with TTM clustering is in more than sufficient detail to meet the SMEs' desires. In fact, in all cases, the SMEs aggregated to a less rigorous level of detail and in no case did the SMEs request additional detail. The average size of the clusters provides one very useful way of comparing them. T-tests were used to determine the significance of differences in the average sizes of the clusters. There was a significant difference between the TDS Preliminary and OMT Preliminary average cluster size ($t = -2.92$, $df=64$, $p = .007$). There was no significant difference between the TDS Final and OMT Preliminary average cluster size ($t = .54$, $df=35$, $p = .594$). These results indicate that the differences in the average number of tasks per cluster in the TDS Final and the OMT Preliminary phases are not statistically significant; i.e., the two averages are about the same.

There are several possible techniques for comparing the content results of the two clustering methods. Most of the techniques rely on determining whether tasks which are clustered together with one method are also clustered together with the other method. The Fowlkes and Mallows (1983) technique has been used previously in a similar study (Perrin, et al., 1986) and is explained in great detail there. The Fowlkes and Mallows statistic has a maximum value of 1.00 (for total agreement of the two groupings) and a minimum value of zero (no agreement between the two). The Fowlkes and Mallows statistic was calculated for the comparison between the TDS Final TTMs and the OMT Preliminary TMs. The Fowlkes and Mallows was statistically significant for this comparison ($F\&M = .987$, $p = .01$), which strongly suggests that the clusters formed with the two techniques are very similar in content.

In addition, the matching of the tasks in the TDS Final clusters and the OMT Preliminary clusters was examined. By taking the TDS clusters one-by-one and picking the OMT cluster which was most like it in terms of the number of matching tasks, the percentage of overlap was determined. For AFS 545X2, the percentage of overlap ranged from 33% to 100%, with an average of 64%.

The Security Police Specialist Comparison

In the Security Police Specialist comparison the TDS Preliminary and TDS Final TTM cluster solutions were compared to the OMT Final TM solution. The task list used for the TDS clustering was somewhat different for two reasons. First, the OSR task list for this AFS underwent an extensive revision by the Security Police Academy; thus, it was very difficult to match the Academy's list to the OSR list. Second, the first task clusters (Preliminary TTMs) were produced using a card sort method whereas the Final TTMs were produced using CODAP

co-performance clustering. Even with these differences, the results provide useful information.

The results of the analysis are summarized in Figure 2. In the TDS Preliminary phase, there were 67 clusters formed from 666 tasks with 115 unclustered tasks. The average cluster size for the TDS Preliminary TTMs was 8.22 tasks. Thirty-three or 49% of the clusters had 5 or fewer tasks. The smallest Preliminary TTM had 1 task and the largest had 34 tasks. In the TDS Final phase, there were 63 clusters formed from 666 tasks, with 4 unclustered tasks. The average cluster size for the TDS Final TTMs was 10.57 tasks. Twenty-four (24) or 38% of the clusters had 5 or fewer tasks. In the OMT Final TMs, there were 34 clusters formed from 411 tasks, with 3 unclustered tasks. The average cluster size for the OMT Final TMs was 12.08 tasks. Ten (10) or 29% of the clusters had 5 or fewer tasks. The smallest OMT Final TM had 1 task and the largest had 46 tasks.

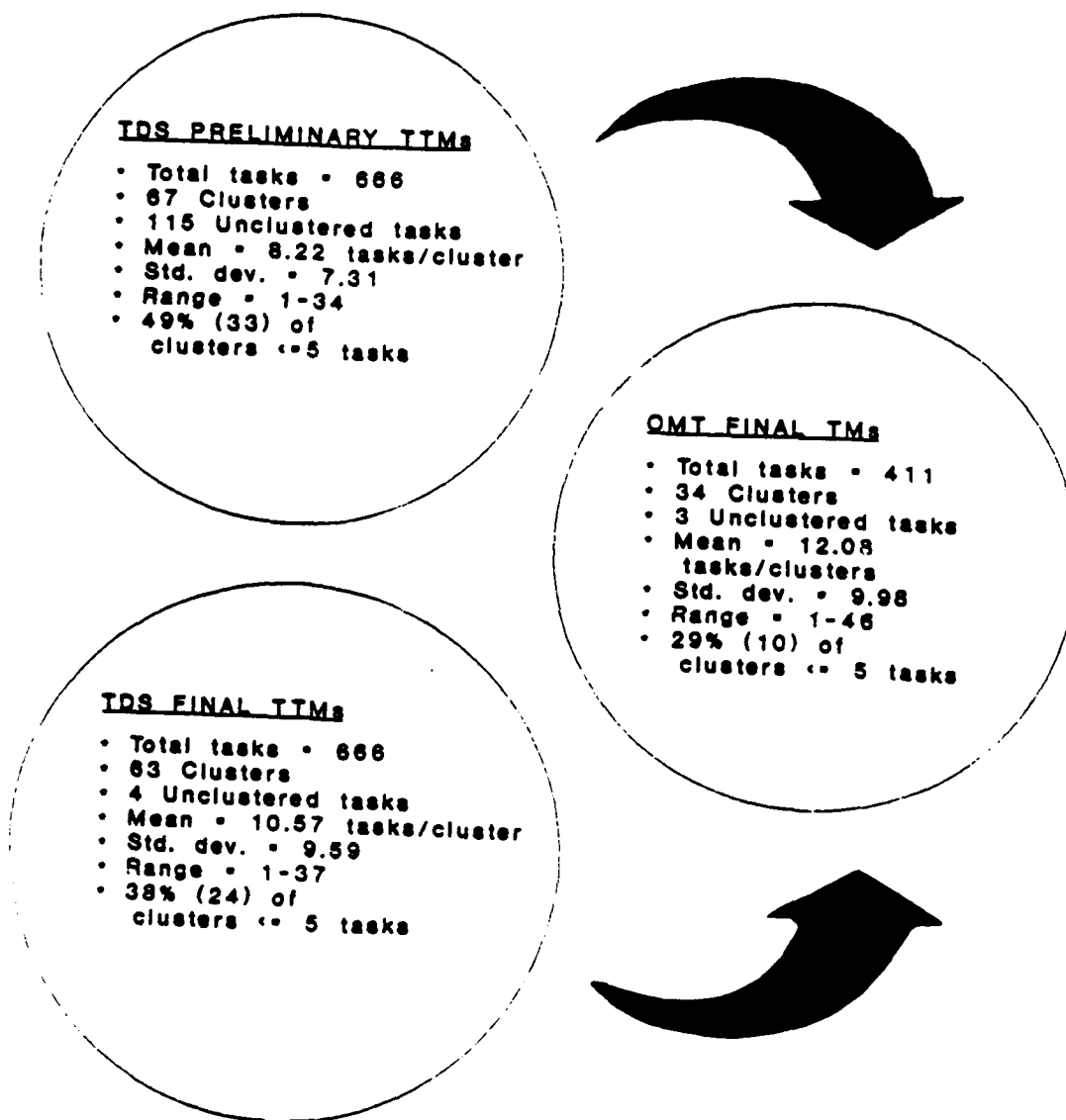


Figure 2. AFS 811XX - Security Police Specialist TDS and OMT Cluster Comparison.

T-tests were also calculated to determine significant differences between the average sizes of the AFSC 811XX clusters. There was a marginally significant difference between the TDS Preliminary and OMT Final average cluster sizes ($t = -1.97$, $df=99$, $p = .055$). There was no significant difference between the TDS Final and the OMT Final average cluster sizes ($t = -.71$, $df=95$, $p = .479$). These results suggest that the TDS Final TTMs and the OMT Final TMs are about the same in terms of cluster sizes.

The Fowlkes and Mallows statistic also was calculated for the phases which were most similar according to the above analysis: the TDS Final and OMT Final phases. The Fowlkes and Mallows statistic was significant ($F\&M = .757$, $p = .01$). This indicates that even though there were different beginning task lists, that those tasks which were on both lists tended to be paired together by both methods. The number of matching tasks in the TDS Final clusters and the OMT Final clusters also was examined. The percentage of overlap ranged from 8% to 100%, with an average of 66%. The results for the AFSC 811XX comparison must be taken as tentative because the differences in the number of tasks in the three solutions may have biased some of the statistics. In each of the three cases, tasks were added or deleted; these tasks would have to be standardized in order to develop equal and comparable beginning task lists.

Having stated this caveat, however, there is no escaping the conclusion that the results of the TDS process, the TDS Final TTMs, are very similar to the OMT TMs in terms of the number of tasks, number of clusters, number of unclustered tasks, and the number of small clusters. Additionally, the Fowlkes and Mallows statistic and overlap results indicate that many of the same tasks are found in clusters from each method.

VI. CONCLUSIONS AND FUTURE RESEARCH CONSIDERATIONS

Conclusions

Phase I of the TDS method, which deals with the statistical clustering of the tasks, is quite advanced and has been established as a good, reliable method. Phase II, which involves the interpretation of the cluster diagram by an analyst, is an essential step and provides a good opportunity for the analyst to include elements from the STS, CDC, or other data bases in making decisions about what will constitute the Preliminary TTMs.

Phases I and II of the TDS clustering method quite effectively take advantage of both the statistical clustering methods and the insights an analyst brings to the process. These preliminary efforts provide the SMEs with some, but not all, of their "grouping" already accomplished. Phase III is an

effective and efficient method of using SMEs in discussion groups. To begin with an unclustered list of tasks would be impractical because clustering would be an immense and time-consuming job. There is still a substantial amount of work for the SMEs to do. They must remove and relocate misplaced tasks, create new clusters as needed, put clusters together with other clusters, and name the clusters. The TDS method is an effective combination of quantitative and qualitative methods.

The OMT clustering method is based on two types of qualitative inputs, one from the analysts and the other from SMEs. Both types of inputs are valuable and provide a substantial basis for constructing training modules, but, as with all essentially qualitative methods, the results may vary with the analyst. Analysts have differing backgrounds, experience, and skills; thus, even well-intentioned efforts often produce differing results. The process could be improved by taking advantage of the state-of-the-art technology in this area -- primarily by including the initial steps of statistical clustering and analyst interpretation.

The comparisons between the two clustering methods lead one to the conclusion that there are definite advantages to the TDS clustering method: The TDS method takes much less time to accomplish, takes advantage of statistical clustering, includes the same potential for analyst input, requires the same input from SMEs and, for all practical purposes, is equivalent in terms of results.

In essence, there are no real methodological barriers to the operational implementation of the TDS technique. The TDS method may be easily adopted and modified to include elements such as OMT Phase III, which focuses on training sequence clustering by the analysts. The documentation on the TDS method is substantial and readily available.

Future Research Considerations

Several ideas which evolved during this research are discussed below. These ideas may aid in improving the clustering techniques which were examined. They are intended as constructive inputs which build upon the valuable and rigorous clustering methods discussed.

OSR Task List Audit

It would be very useful whenever either of the two clustering methods is used to have an OSR task list update accomplished before the clustering is attempted. The OSR update follows certain procedures which should be adhered to during each audit. The relatively unstructured method of adding, deleting, and modifying tasks on the total task list

does not lead to better inputs from the SMEs in either the TDS or the OMT SME workshops. The focus in the workshops should be on the clusters formed from recently audited task lists which the analyst can be reasonably sure represent the current state of work in the AFS. There is quite enough work for the SMEs to do in discussing the clusters and making sense out of them and reshuffling tasks without having to worry about tasks which may not be on the list or should not be on the list.

Task Training Bundles (TTBs)

The TDS preliminary clustering effort takes place before going into the field. This effort is effective in establishing a basis for discussion in the SME workshops and perhaps may be improved by slightly modifying the clustering. At present, the goal is to define the modules themselves and then let the SMEs alter any unclustered single tasks or those modules which are quite large. With this procedure, there is a potential danger of the SMEs' shifting individual tasks or groups of tasks without giving much thought to the individual jobs or groups of jobs represented in the cluster. An alternative which readily suggests itself for the preliminary phase is this: to define smaller but more tightly clustered "bundles" of tasks which the co-performance data strongly suggest go together, instead of defining such large modules. In all likelihood, this would result in more clusters or "bundles," with fewer tasks in each than is presently the case. In this alternative, the emphasis would be placed on creating tight "Task Training Bundles" (TTBs) of tasks which would serve as the stimulus material for the SMEs to form their own clusters. It is still quite possible that many of the tight "bundles" would still be considered as TTMs by the SMEs.

Additional Clustering Variables

The TDS method uses co-performance to group tasks together into clusters. This is a very good variable to use in most cases involving training because it reflects the manner in which work is actually performed in the field. However, it may not be applicable to some types of decisions by some types of researchers or users such as in Phase III of the OMT method, which focuses on training sequence clustering and uses such variables as ease of learning, dependency, and functional grouping. The TDS statistical clustering method would be even more attractive if the procedures allowed clustering by such variables or allowed the input of data for additional variables. An example of this type of clustering is found in Project SUMMA. Project SUMMA (Small Unit Maintenance Manpower Analyses), which is being conducted by the Air Force Human Resources Laboratory's Logistics and Human Factors Division, has explored the use of performance and

knowledge variables to cluster tasks across AFSs in order to develop potential new AFSs (Lamb, Eckstrand, Seman, & Lindeman, 1987).

SME Workshop Enhancement

Both of the clustering methods use SME workshops. The TDS method relies on groups of 4-7, which research has indicated as an optimal size for such groups (Payne & Cooper, 1981). The OMT method uses groups or individual SMEs. The input from SMEs should be obtained by only one method--groups or individuals. If results are mixed, the quality of the resultant clusters will be diminished and not comparable. The advantages of the small groups of SMEs are substantial and are worth the logistical effort of organizing the workshops.

Small group research also suggests the importance of equal status in discussion groups such as these (Borgman, 1975; Ridgeway, 1983). The AFSC 545X2 SME workshop examined in this study just happened to be composed of four non-commissioned officers of equal rank and functioned quite effectively. In future SME workshops, it would be wise to purposely compose the groups with members of equal rank whenever possible.

The SME small group workshops are an excellent way of obtaining inputs from several people and discussing issues which arise in the cluster resolution process. Memories of the work under examination are stimulated and enhanced by the discussions. Also, the type of discussion that is needed to make decisions about creating and combining TTMs is possible in the workshops. Still, it may be possible to improve these workshops and use the SMEs in an even more effective manner. The suggestion above about creating the TTMs as the stimulus material for discussion is one possibility for improvement. A second possibility involves changing the way in which TTMs are presented to SMEs. Presently, the SMEs are given sheets with lists of the task numbers, task names, etc., usually with all the tasks in one analyst-defined TTM on one sheet. There may be quite a number of TTMs and a resultant high number of sheets to be shuffled by the SMEs during their discussions. For example, there were 46 Preliminary TTMs in AFSC 545X2 analyzed for this study. The SMEs line through a task as they move it from one TTM and write it in on the page of another TTM. This practice is replete with the potential for errors and a good deal of time is spent by the SMEs in simple tabulation work. This type of shuffling and cutting and pasting from TTM to TTM seems an excellent candidate for performance on a portable microcomputer. Most off-the-shelf word processing software packages would be able to handle this type of work with little or no modification. An additional piece of hardware such as a Kodak Datashow Projection device (which has a liquid crystal display) can be hooked up to a portable computer and used with a standard Vu-Graph projector

to project the small computer screen on a large screen or wall. An additional small portable printer would give the SMEs instant hardcopy to peruse and discuss, and at the end of the session they could print out the final TTMs and tabulate the results for accuracy. In this scenario, the analyst, who is familiar with the software and hardware, would probably be the person at the computer doing all of the cutting, pasting, and shuffling. The SMEs would be doing the discussing and providing direction for computer input. Immediate feedback in the form of an updated clean copy on the computer screen and a hardcopy should elicit more and better discussion and, therefore, more expertly defined TTMs.

Additional SME Input

Consideration should be given to adding an SME to either the TDS or the OMT clustering process from the beginning. It is quite possible that the use of one individual on a TDY basis for 3 or 4 weeks prior to the workshop could greatly facilitate the work of the analyst and assure the smooth conduct of the SME workshop to follow and the validity of the clusters which result.

Additional Comparisons

The present investigation focused on AFSC 545X2. It would be prudent to extend the study to other AFSSs to assure similar results for types of work other than that represented by this AFS.

This study focused on blocks A and B in the AFSC 545X2 comparison illustrated in Figure 3. The study should be extended to the unexamined blocks when data become available to compare the final results of the OMT method with the final results of the TDS method.

Heating System Specialist (AFSC 545X2) Comparison

		TDS	
		Preliminary	Final
O	Preliminary	A	B
M			
T	Final	C	D

Figure 3. Bases for Additional Comparisons.

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APPENDIX A: The TDS Co-performance Clustering Process

Co-performance task clustering is a multi-step process. The discussion below describes the steps involved in constructing co-performance task clusters using CODAP data files and clustering programs.

Step 1

The raw data needed to cluster tasks come from the job inventories returned to the USAF Occupational Measurement Center. Job Inventories are sent to job incumbents who respond as to what tasks they perform. Figure A-1 is an example of a page from the job inventory for Air Force specialty 545X2 (Heating Specialist).

	CHECK	Time spent present job								
	IF DONE NOW	RATE								
		1. Very small amount. 2. Much below avg. 3. Below avg. 4. Slightly below avg. 5. About avg. 6. Slightly above avg. 7. Above avg. 8. Much above avg. 9. Very large amount.								
119. Install aquastats		1	2	3	4	5	6	7	8	9
120. Install black iron steam condensate lines		1	2	3	4	5	6	7	8	9
121. Install boiler gauge glasses		1	2	3	4	5	6	7	8	9
122. Install boiler safety valves		1	2	3	4	5	6	7	8	9

Figure A-1. Format of a Job Inventory.

Step 2

From all the cases (people) responding, a data file is constructed. The data file is said to be case-oriented (see Figure A-2). The ratings entered in the survey identify the cases who do/don't do the task (1=do, 0=don't do).

		CASE NO.			
		1	2	3	4
T A S K	A	1	1	1	1
	B		1	1	
	C	1	1	1	
	D		1		

Figure A-2. Example of a Case-oriented Data File From a Job Inventory.

Step 3

Now, in order to cluster tasks, the data file in step 2 must be transposed to make it task-oriented as opposed to case-oriented, because the computer can read the data file only in one direction. The CODAP program "XPOSE" performs this function. Figure A-3 shows a task-oriented data file.

		TASK			
		A	B	C	D
C A S E #	1	1		1	
	2	1	1	1	1
	3	1	1	1	
	4	1			

Figure A-3. A task-oriented data file.

Step 4

The computer now runs the "OVLAP" program, which computes a similarity measure between each pair of tasks by comparing the corresponding responses for all cases, using the following formula:

$$\text{Task co-performance} = \frac{1}{2} \frac{C_{AB} + C_{BA}}{t_A + t_B} \times 100$$

C_{AB} = the number of co-occurrences of the two tasks

t_A = the number of cases reporting that they perform task "A"

t_B = the number of cases reporting that they perform task "B"

As an example, let's compute the similarity measure of a pair of tasks. According to the matrix in step 3, tasks "A" and "B" co-occur two times. Task "A" occurs a total of four times, while task "B" occurs a total of two times. Thus...

$$\text{Co-performance AB} = \frac{1}{2} \times \frac{2}{4} + \frac{2}{2} \times 100 = 75\%$$

The same computation is performed for each pair of tasks. The computer constructs a file containing a similarity matrix from the results of the computations. Because every task overlaps with itself 100%, the cells on the diagonal will always be 100's. The matrix for Air Force specialty 545X2 involving 453 tasks contained 205,209 cells in a format similar to that shown in Figure A-4. The matrix is now in a format to be read by another CODAP program which clusters tasks. The computational example shown in Figure A-4 contains only four tasks; however, the CODAP clustering programs are capable of handling up to 3,000 tasks.

BEGINNING MATRIX: 4 GROUPS

TASK A B C D

A	100	75	87.5	62.5
B	75	100	83.3	75
C	87.5	83.3	100	66.7
D	62.5	75	66.7	100

FIGURE A-4. The Similarity Matrix Constructed by the OVERLAP Program and Read by the GROUP Program to Cluster Tasks.

Step 5

In this step, the CODAP program "GROUP" reads the similarity matrix constructed in step 4. Using the average linkage clustering procedure, GROUP organizes the most similar groups of tasks into hierarchical clusters (starting with groups consisting of a single task each). Thus, the "average linkage" value for groups A and C (which have the highest similarity value, excluding the diagonal values) is as follows:

Average overlap "between" groups A and C: 75% (as shown in Figure A-4)

When GROUP merges groups A and C, it also computes a measure of group homogeneity called the average overlap "within" the new group just formed. The average overlap within is calculated by adding all the values in the cells that comprise the new group and dividing by the number of cells in the new group. Again, refer to the matrix in step 4 for this example:

Average overlap "within" group AC:

$$\frac{2(100) + 2(AC)}{2^2} = \frac{2(100) + 2(75)}{4} = \frac{350}{4} = 87.5\%$$

With each iteration or stage of the clustering process the matrix in step 4 is collapsed. Figures A-5 through A-7 show the similarity matrix collapsing during three stages, and the associated overlap computations. Notice that the first cell contains the overlap "within" measure of group AC while all other cells contain overlap "between" measures.

STAGE 3: 3 GROUPS REMAINING

TASK	AC	B	D
AC	87.5	79.2	64.6
B	79.2	100	75
D	64.6	75	100

FIGURE A-5. The Similarity Matrix After Groups A and C Have Been Merged.

The stage 3 matrix required the following computations to collapse rows/columns A and C into row/column AC: Average overlap "between" groups AC and B:

Average overlap "between" groups AC and B:

$$\frac{AB + CB}{2} = \frac{75 + 83.3}{2} = \frac{158.3}{2} = 79.2\%$$

Average overlap "between" groups AC and D:

$$\frac{AD + CD}{2} = \frac{62.5 + 66.7}{2} = \frac{129.2}{2} = 64.6\%$$

Step 6

The next most similar pair of groups is AC with B, which have 79.2% overlap. The merging of these two groups results in the matrix shown in Figure A-6.

STAGE 2: 2 GROUPS REMAINING

	TASK	ABC	D
ABC	88.0	68	
D	68	100	

Figure A-6. The Similarity Matrix After Groups AC and B Have Been Merged.

The stage 2 matrix required the following computations to compute the average overlap "within" and to collapse rows/columns AB and C into rows/columns ABC:

Average overlap "within" groups ABC:

$$\frac{3(100) + 2(AB + AC + BC)}{3^2} = \frac{3(100) + 2(75 + 87.5 + 83.3)}{9} =$$

$$\frac{796.6}{9} = 88.0\%$$

Average overlap "between" groups ABC and D:

$$\frac{AD + BD + CD}{3} = \frac{62.5 + 75 + 66.7}{3} = \frac{204.2}{3} = 68.1\%$$

Step 7

The next most similar pair of groups (the only pair remaining) is ABC with D. The merging of these two groups results in the matrix shown in Figure A-7.

STAGE 1: 1 GROUP REMAINING

TASK	ABCD
ABCD	81.2

Figure A-7. The Similarity Matrix After Groups ABC and D Have Been Merged Into a Single Group (Final Iteration).

Average overlap "between" groups ABC and D = 68%, as shown in Figure A-6.

Average overlap "within" group ABCD:

$$\frac{4(100) + 2(AB + AC + AD + BC + BD + CD)}{4^2} =$$

$$\frac{4(100) + 2(75 + 87.5 + 62.5 + 83.3 + 75 + 66.7)}{16} = \frac{1300}{16} = 81.2\%$$

Step 8.

Finally, the CODAP program DIAGRM prints a picture or diagram showing how the tasks in a clustering merged. Figure A-8 is an example of a small section of the actual diagram produced for AFS 545X2 (Heating Specialist), and Figure A-9 provides an interpretation of the contents of a diagram data block, using stage (group) 0237 from Figure A-8 as the example. The entire diagram produced for the 453 tasks clustered in AFS 545X2 is, of course, very large. To help you better understand the diagram, each data block has been marked with the letters A through J to show how groups of tasks merged in this section of the diagram.

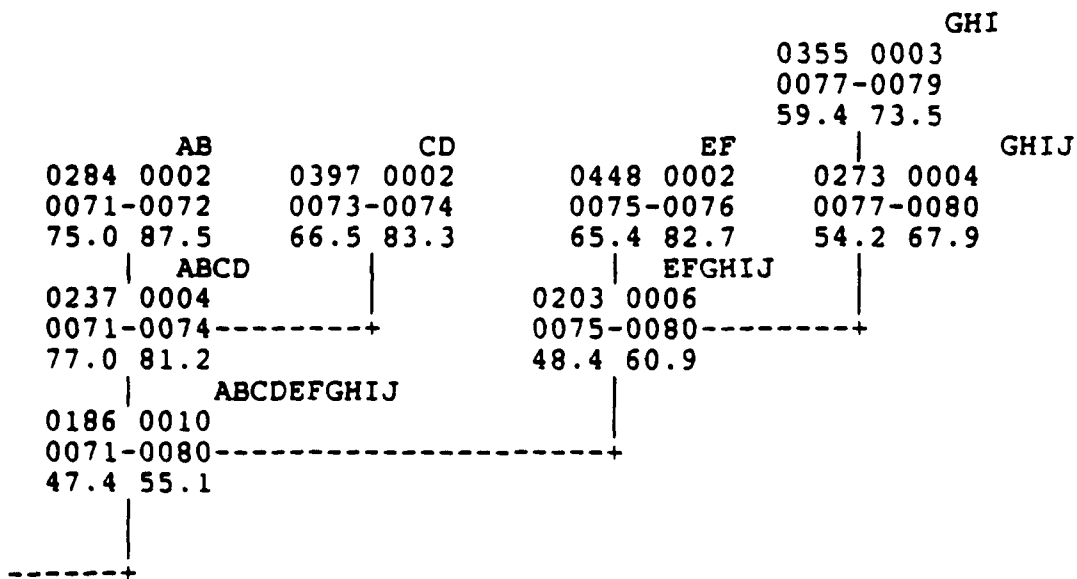


Figure A-8. A Section of a Diagram Produced by the CODAP DIAGRM Program.

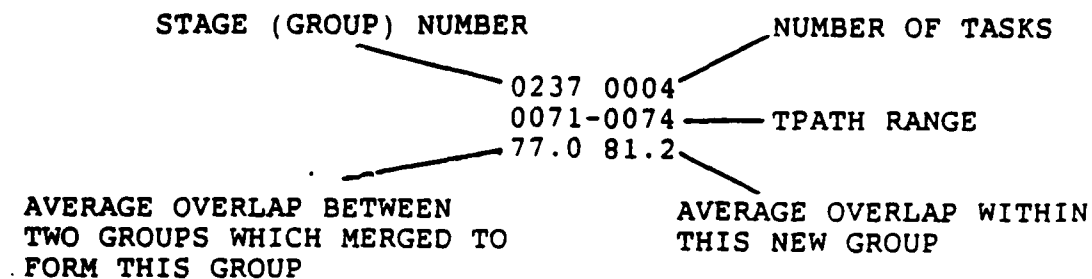


Figure A-9. Interpretation of the Contents of a Diagram Data Block.

An essential tool for interpreting the diagram is a listing of the tasks sorted, in the same sequence as they were clustered ("TPATH" sequence). The CODAP program that prints this listing is the PRTFAC (Print Factors) program. In addition to the "between" and "within" overlap measures on the diagram, the training analyst must also consult the PRTFAC to make decisions about selecting appropriate task clusters. Figure A-10 is that part of the PRTFAC corresponding to the diagram in Figure A8. The duty designation (DTY), task sequence number, and title are from the job inventory. As can be seen by inspecting this section of the PRTFAC report, tasks with TPATH SEQ NUM 71-80 have to do with the installation and maintenance of forced air heating systems. Thus, the PRTFAC data confirm that stage (Group) 0237, which includes TPATH 71-80, is a meaningful task cluster.

TPATH SEQ NUM	D T Y	TASK SEQ NUM	TITLE
.	.	.	.
71	F	135	Install distribution lines
72	K	325	Remove or replace solenoid valves
73	F	170	Install solenoid valves
74	G	196	Mix and apply powered insulation
75	F	159	Install pre-formed insulation
76	F	151	Install insulating materials on pipes other than pre-formed insulation
77	K	310	Remove or replace burners in forced air heating systems
78	K	315	Remove or replace electrical fans
79	M	417	Trace steam distribution systems
80	M	391	Inspect steam traps . . .

Figure A-10. Section of the PRTFAC report produced for AFS 545X2.

APPENDIX B. TDS Preliminary Clusters (TTMs)
5452X (Heating System Specialist)

Clusters	# of Tasks
1	29
2	5
3	9
4	4
5	28
6	2
7	41
8	5
9	3
10	10
11	12
12	2
13	11
14	22
15	2
16	5
17	3
18	2
19	4
20	2
21	17
22	15
23	8
24	2
25	41
26	3
27	2
28	4
29	10
30	3
31	1
32	10
33	2
34	2
35	7
36	3
37	2
38	33
39	5
40	48
41	5
42	5

43	4
44	8
45	6
46	6

Total = 453 tasks

1. TDS clusters are often referred to as Task Training Modules (TTMs) and are untitled in the Preliminary Phase

TASK NUMBER**TITLE****Preliminary
TTM #1**

1 G 207	Thread pipe by machine
2 G 194	Measure and cut pipe by machine
3 G 193	Measure and cut pipe by hand
4 G 206	Thread pipe by hand
5 G 192	Measure and cut copppe tubing
6 K 312	Remove or replace check valves
7 K 317	Remove or replace gauges
8 G 195	Measure and cut pre-formed insulation
9 K 291	Clean strainers
10 K 328	Remove or replace strainers
11 K 316	Remove or replace filters
12 K 294	Inspect and clean filters
13 K 320	Remove or replace insulating materials on pipes other than asbestos insulation
14 K 309	Remove asbestos insulation on ducts or pipes
15 K 300	Inspect motor or fan bearings
16 K 299	Inspect drive belts
17 K 289	Clean and lubricate motor or fan bearings
18 K 288	Clean and lubricate blower bearings
19 K 296	Inspect blower bearings
20 K 314	Remove or replace couplings or pulleys
21 K 279	Adjust couplings or pulleys
22 K 284	Align couplings or pulleys
23 K 281	Adjust drive belts
24 K 285	Align drive belts
25 K 280	Adjust dampers
26 K 298	Inspect dampers
27 K 302	Lubricate fans
28 K 301	Lubricate air handling units
29 G 189	Lubricate copper tubing systems

Total 29**Preliminary
TTM #2**

1 K 311	Remove or replace centrifugal water pumps
2 K 323	Remove or replace packing on centrifugal water pumps
3 K 321	Remove or replace mechanical water pump seals
4 K 283	Adjust heater regulating valves
5 K 330	Remove or replace water regulation valves

TASK NUMBER

TITLE

Total 5

Preliminary
TTM #3

1	I 258	Reset circuit breakers
2	I 252	Remove or replace fuses
3	I 251	Remove or replace electric motors
4	I 243	Inspect fuses or curcuit breakers
5	I 263	Wire-in motors to power sources
6	H 208	Adjust electrical thermostats or pressure switches
7	H 227	Remove or replace automatic heating controls or thermostats
8	H 229	Remove or replace electrical controls
9	H 230	Remove or replace electrical wiring on controls

Total 9

Preliminary
TTM #4

1	G 191	Lubricate heating blowers
2	G 201	Remove or replace heating blowers
3	G 190	Inspect heat exchangers
4	G 186	Clean heat exchangers

Total 4

Preliminary
TTM #5

1	F 157	Install packing
2	F 126	Install check valves
3	F 145	Install gauges
4	F 121	Install boiler gauge glasses
5	F 122	Install boiler safety valves
6	F 129	Install circulation pumps
7	F 138	Install feed or condensate pumps
8	F 136	Install electric motors
9	F 132	Install couplings or pulleys
10	F 125	Install centrifugal water pumps
11	F 141	Install filters
12	F 120	Install black iron steam condensate lines
13	M 403	Remove or replace black iron steam condensate lines
14	F 175	Install steam heating system valves or

TITLE

Total 28

Total 2

34

TASK NUMBERTITLE

chambers
12 M 373 Drain steam heating system boilers
13 M 375 Fill steam heating system boilers
14 M 409 Remove or replace steam heating system boiler
gauge glasses
15 M 410 Remove or replace steam heating system boiler
manhole or handhole cover gaskets
16 M 368 Clean steam heating system boiler gauge
glasses
17 M 369 Clean steam heating system boiler tubes
18 M 377 Inspect and wash down steam heating system
boiler water sides
19 M 361 Clean and inspect steam heating system
combustion chambers
20 M 423 Check steam heating system boiler tricocks
21 M 381 Inspect fire tubes for leaks or soot build-up
22 M 380 Inspect feed water controls
23 M 363 Clean water controls (Mcdonnel-Miller)
24 M 363 Clean feed water controls (Mcdonnel-Miller)
25 M 405 Remove or replace boiler safety valves
26 M 413 Remove or replace steam heating system safety
valves
27 M 414 Remove or replace steam heating system boiler
feed or condensate pumps
28 M 411 Remove or replace steam heating system boiler
feed or condensate pumps
29 M 415 Remove or replace steam heating system valves
or fittings other than safety or pressure
relief
30 M 392 Inspect water tubes for leaks
31 N 420 Adjust steam heating system feed water
regulators
32 N 421 Adjust steam heating system steam regulation
valves
33 M 374 Drain steam system other than boilers
34 N 425 Perform steam heating system boiler draft
control operational checks
35 N 427 Perform steam heating system combustion
efficiency analyses
36 M 370 Clean tube sheets
37 M 390 Perform steam heatings system refractory
repairs
38 M 396 Isolate steam heating system boiler flame
control malfunctions
39 M 400 Rebuild steam traps
40 M 399 Rebuild feed water controls (Mcdonnel-Miller)
41 M 318 Inspect steam heatings system expansion
joints

TASK NUMBER**TITLE**

Total 41

Preliminary
TTM #8

1 L 340	Inspect gas burners
2 L 334	Adjust gas burner fuel-air ratios
3 L 351	Perform gas burner operational checks
4 L 356	Remove or replace gas burners
5 F 144	Install gas burners

Total 5

Preliminary
TTM #9

1 K 282	Adjust valve and damper linkages
2 K 329	Remove or replace valve and damper linkages
3 F 183	Install valve or damper linkages

Total 3

Preliminary
TTM #10

1 L 339	Inspect fuel lines or fittings
2 L 342	Inspect oil burners
3 L 335	Adjust oil burner fuel-air ratios
4 L 353	Perform oil burner operational checks
5 L 357	Remove or replace oil burners
6 L 360	Verify quantity of fuel oil in tanks
7 L 344	Inspect oil storage tanks
8 L 345	Inspect oil tanks for water or other impurities
9 L 348	Lubricate oil burners
10 F 153	Install oil burners

Total 10

Preliminary
TTM #11

1 I 257	Remove or replace transformers
2 I 262	Test transformers
3 F 180	Install transformers

TASK NUMBER**TITLE**

4 F 137	Install electrical controls
5 I 254	Remove or replace relays
6 F 165	Install relays
7 H 239	Test safety control operations
8 I 259	Reset motor thermal overloads
9 I 248	Isolate electrical system malfunctions
10 I 241	Inspect electrical circuits
11 I 242	Inspect electrical power supplies
12 I 249	Measure motor current draw

Total 12

Preliminary
TTM #12

1 K 297	Inspect centrifugal water pump operations
2 K 277	Adjust centrifugal water pump

Total 2

Preliminary
TTM #13

1 G 205	Remove or replace unit heaters
2 F 182	Install unit heaters
3 G 204	Remove or replace space heaters
4 F 172	Install space heaters
5 G 197	Remove or replace boilers
6 F 123	Install boilers
7 G 199	Remove or replace furnaces
8 F 142	Install furnaces
9 F 148	Install heating blowers
10 G 200	Remove or replace heat exchangers
11 F 147	Install heat exchangers

Total 11

Preliminary
TTM #14

1 R 478	Fill low or medium temperature water heating systems with water and bleed air from systems
2 R 477	Drain or flush low or medium temperature water heating system boilers
3 R 479	Inspect low or medium temperature water heating system boilers or leaks
4 R 481	Light-off low or medium temperature water

TASK NUMBER

TITLE

5 R 485	heating system boilers Perform low or medium temperature water heating system operational checks
6 R 483	Perform low or medium temperature water heating system boiler pre-operational checks
7 R 482	Perform aquastat operational checks
8 R 480	Lay up low or medium temperature water heating system boilers
9 Q 467	Inspect low or medium temperature water heating system pressure relief valves
10 Q 465	Clean low or medium temperature water heating system boilers
11 Q 472	Remove or replace circulating pumps
12 Q 475	Remove or replace low or medium temperature water heating system pressure relief valves
13 Q 476	Remove or replace pressure regulating valves
14 Q 473	Remove or replace low or medium temperature water heating air bleed valves
15 Q 474	Remove or replace low or medium temperature water heating system distribution lines
16 Q 471	Remove or replace aquastats
17 Q 468	Isolate low or medium temperature hot water heating system boiler flame control malfunctions
18 Q 469	Isolate one or two pipe water heating system malfunctions
19 Q 466	Clean one or two pipe water heating systems
20 Q 470	Perform low or medium temperature water heating system refractory repair
21 R 486	Recharge low or medium temperature water heating system closed expansion tanks
22 R 484	Perform low or medium temperature water heating system combustion efficiency analyses

Total 22

Preliminary
TTM #15

1 K 313	Remove or replace chemical feeding equipment
2 F 127	Install chemical feeding equipment

Total 2

Preliminary
TTM #16

TASK NUMBER

TITLE

1 H 215	Analyze pressure or temperature readings
2 F 168	Install safety valves other than boiler safety valves
3 F 150	Install insulating materials on ducts other than pre-formed insulation
4 K 293	Inspect and clean ducts
5 K 295	Inspect and clean fresh air supply systems

Total 5

Preliminary
TTM #17

1 M 376	Inspect and clean steam heating system smokesatcks
2 M 395	Insulate low pressure steam heating system combustion chamber doors
3 M 408	Remove or replace low pressure steam heating combustion chamber doors

Total 3

Preliminary
TTM #18

1 K 333	Silver solder lines or fittings
2 K 306	Oxyacetylene weld lines, bracings, or fittings

Total 2

Preliminary
TTM #19

1 G 203	Remove or replace sectional boiler sections
2 G 146	Install generator or system pumps
3 F 164	Install reciprocating pumps
4 F 166	Install rotary positive displacement pumps

Total 4

Preliminary
TTM #20

1 G 187	Connect exhaust outlets to flues or stacks
2 G 188	Connect heating outlets to ducts

TASK NUMBER**TITLE**

Total 2

Preliminary
TTM #21

1 H 209	Adjust electronic controls
2 H 232	Remove or replace electronic controls
3 H 231	Remove or replace electronic control components
4 H 226	Isolate electrical control malfunctions
5 H 216	Calibrate electrical thermostats or pressure switches
6 H 219	Calibrate motorized valves
7 I 253	Remove or replace motor starters
8 I 255	Remove or replace starting or running capacitors
9 F 173	Install starting or running capacitors
10 F 152	Install motor starters
11 I 260	Test motor running or starting windings
12 I 261	Test starting or running capacitors
13 F 179	Install timers
14 H 235	Remove or replace oil safety switches
15 F 155	Install oil safety switches
16 I 250	Remove or replace circuit breakers
17 F 128	Install circuit breakers

Total 17

Preliminary
TTM #22

1 J 269	Blowdown condensate from air tanks
2 J 272	Inspect compressor oil levels
3 J 271	Clean and lubricate compressors
4 J 264	Adjust air compressor belts
5 J 268	Align air compressor belts
6 J 265	Adjust air compressor pressure controls
7 F 158	Install pneumatic controls
8 J 267	Adjust pressure regulators
9 J 276	Remove or replace pressure controls
10 J 266	Adjust pneumatic controls
11 J 275	Remove or replace pneumatic controls
12 J 273	Isolate pneumatic control malfunction
13 J 270	Calibrate pneumatic controls
14 J 274	Perform pneumatic safety valve operational checks

TASK NUMBER**TITLE**

15 K 307

Perform adjustments at control panels to
remotely reposition control devices

Total 15

Preliminary
TTM #23

1 V 539

Draw boiler water samples

2 V 543

Mix chemical required to treat water

3 V 540

Draw condensate return water samples

4 V 541

Inspect chemical reagents and test
equipment

5 V 542

Maintain boiler chemical storage areas

6 E 106

Make entries on AF Forms 1458 (daily
steam boiler plant operation log)

7 E 107

Make entries on AF Forms 1459 (water
treatment operating log for steam and hot
water boilers)

8 E 108

Make entries on AF Forms 1404 (monthly
steam boiler plant operating log)

Total 8

Preliminary
TTM #24

1 M 364

Clean mud drums

2 M 366

Clean steam drums

Total 2

Preliminary
TTM #25

1 T 521

Blowdown central steam plant boiler water
columns

2 T 522

Check central steam plant boiler water level

3 T 526

Light-off central steam plant boilers

4 T 523

Drain central steam plant boilers

5 T 530

Perform central steam plant boiler
pre-operational checks

6 T 525

Lay-up central steam plant boilers wet

7 S 509

Prepare boilers for inspection

8 S 499

Inspect central steam plant boiler manhole
and handhole covers

9 S 497

Inspect central steam plant boiler feed and

<u>TASK NUMBER</u>	<u>TITLE</u>
10 S 493	condensate pumps Fill central steam plant boiler and check for leaks
11 S 513	Remove or replace central steam plant boiler manhole and handhole cover gaskets
12 S 514	Remove or replace central steam plant boiler gauge glasses
13 S 489	Clean central steam plant boiler gauge glasses
14 S 490	Clean central steam plant boiler tubes
15 S 496	Inspect and wash down central steam plant steam boiler water sides
16 S 500	Inspect central steam plant combustion chambers
17 S 494	Inspect and clean central steam plant combustion chambers
18 S 503	Inspect feed water regulators
19 S 517	Remove or replace central steam plant valves or fittings other than safety or pressure relief
20 S 516	Remove or replace central steam plant safety valves
21 S 515	Remove or replace central steam plant boiler feed and condensate pumps
22 S 512	Regulate steam output of boilers
23 S 505	Perform automatic boiler control operational checks
24 S 506	Perform central steam plant boiler draft control operational checks
25 S 504	Isolate central steam plant boiler flame control malfunctions
26 S 508	Perform central steam plant refractory repair
27 T 532	Perform corrective action in case of boiler safety shutdowns
28 T 531	Perform central steam plant combustion efficiency analyses
29 T 520	Adjust central steam plant regulating valves
30 S 502	Inspect central steam plant steam indicating and recording equipment
31 S 501	Inspect central steam plant deaeration
32 S 491	Clean central steam plant deaeration equipment
33 S 507	Perform central steam plant boiler or expansion tank hydrostatic tests
34 S 510	Rebuild feed water regulators
35 S 495	Inspect and clean central steam plant smokestacks
36 T 524	Lay-up central steam plant boilers dry

TASK NUMBER

TITLE

37 S 498	Inspect central steam plant boiler fusible plugs
38 S 518	Remove or replace fusible plugs
39 M 383	Inspect steam heating system boiler fusible plugs
40 M 404	Remove or replace boiler fusible plugs
41 F 143	Install fusible plugs

Total 41

Preliminary
TTM #26

1 M 389	Inspect steam heating system steam indicating and recording equipment
2 M 387	Inspect steam heating system dearators
3 N 419	Adjust heating system deaerators

Total 3

Preliminary
TTM #27

1 S 487	Clean and lubricate central steam plant steam indicating and recording equipment
2 S 488	Clean central steam plant boiler airflow switches

Total 2

Preliminary
TTM #28

1 H 222	Clean and service central heating plant control panels
2 H 225	Isolate central heating plant control panel malfunctions
3 H 228	Remove or replace central heating plant control panels
4 F 124	Install central heating plant control panels

Total 4

Preliminary
TTM #29

TASK NUMBER**TITLE**

1 M 379	Inspect demineralizers or water softeners
2 M 372	Drain demineralizers or water softeners
3 M 397	Perform demineralizer or water softener operational checks
4 N 418	Adjust demineralizers or water softeners
5 V 544	Monitor demineralizer or water softeners
6 V 538	Clean demineralizers or water softeners
7 N 428	Test brine solution
8 V 547	Recharge demineralizers
9 F 134	Install demineralizers or water softners
10 M 406	Remove or replace demineralizer or water softeners

Total 10

Preliminary
TTM #30

1 L 354	Perform oil storage tank preventive maintenance
2 L 341	Inspect liquid petroleum tanks
3 L 352	Perform liquid petroleum tank preventive maintenance

Total 3

Preliminary
TTM #31

1 K 280	Arc weld line, bracings, or fittings
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Total 1

Preliminary
TTM #32

1 L 347	Lubricate gas burners
2 M 362	Clean and lubricate steam heating system steam indicating and recording trumpeting
3 M 367	Clean steam heating system boiler airflow switches
4 M 365	Clean new tube ends with emery cloth

TASK NUMBER**TITLE**

5 M 371	Cut tubes to prescribed length
6 M 402	Remove damaged tubes
7 M 394	Install new tubes with rolling device
8 M 393	Install new tubes by hand
9 M 412	Remove or replace steam heating system dearators
10 M 416	Remove or replace thermosetting resin pipe

Total 10

Preliminary
TTM #33

1 K 327	Remove or replace steam or temperative recording equipment
2 F 177	Install steam or temperature recording equipment

Total 2

Preliminary
TTM #35

1 H 236	Remove or replace pressure potentiometers
2 F 162	Install pressure potentiometer
3 H 217	Calibrate electronic controls
4 H 220	Calibrate oil safety switches
5 H 224	Inspect reheating systems
6 F 149	Install humidistats
7 H 211	Adjust humidity equipment other than humidistats

Total 7

Preliminary
TTM #36

1 K 303	Measure airflow or pressure with manometers
2 K 304	Measure airlflow with anemometers
3 K 305	Measure airflow with velometers

Total 3

Preliminary

TASK NUMBER**TITLE****TTM #37**

- | | |
|---------|---|
| 1 W 576 | Removes or replace interior gas service lines |
| 2 W 572 | Read meters |

Total 2**Preliminary
TTM #38**

- | | |
|----------|---|
| 1 O 439 | Inspect safety valves |
| 2 O 435 | Inspect high temperature water heating system boilers for leaks |
| 3 O 436 | Inspect high temperature water heating system pressure relief valves |
| 4 O 434 | Inspect high temperature water heating distribution systems |
| 5 O 433 | Fill high temperature water heating systems with water and bleed air from systems |
| 6 O 432 | Drain or flush high temperature water heating system boilers |
| 7 O 430 | Clean high temperature water heating system boilers |
| 8 O 437 | Inspect high temperature water heating system conduits |
| 9 O 438 | Inspect pressurization systems |
| 10 P 462 | Perform high temperature water heating system operational checks |
| 11 P 459 | Light-off high temperature water heating systems |
| 12 P 460 | Perform high temperature water heating system boiler pre-operational checks |
| 13 P 463 | Perform high temperature water heating system control valve operational checks |
| 14 P 451 | Perform high temperature water heating system combustion efficiency analyses |
| 15 P 458 | Adjust high temperature water heating system regulating valves |
| 16 O 451 | Remove or replace high temperature water heating system safety valves |
| 17 O 452 | Remove or replace high temperature water pressure relief valves |
| 18 O 450 | Remove or replace high temperature water heating system centrifugal water pumps |
| 19 O 449 | Remove or replace high temperature water heating system air bleed valves |

TASK NUMBERTITLE

20 O 443	Lubricate high temperature water heating system control valves
21 O 441	Isolate high temperature water heating system boiler flame control malfunctions
22 O 442	Lay-up high temperature water heating system boilers
23 O 447	Perform high temperature water heating system refractory repairs
24 O 446	Perform high temperature water heating system boiler or expansion tank hydrostatic tests
25 O 440	Inspect temperature recording equipment
26 O 431	Clean temperature recording equipment
27 P 464	Recharge high temperature water heating system closed expansion tanks
28 O 453	Remove or replace reciprocating pumps
29 O 454	Remove or replace rotary
30 O 445	Pack or lubricate high temperature water heating system expansion joints
31 O 429	Align high temperature water heating system expansion joints
32 E 105	Make entries on AF Form 1165 (monthly temperature water plan operating log)
33 E 104	Make entries on AF Forms 1163 (monthly high temperature water distribution system operating log)

Total 33

Preliminary
TTM #39

1 O 444	Lubricate temperature recording equipment
2 O 448	Remove or replace corrosion testers in distribution lines
3 O 457	Submit corrosion testers for analysis
4 O 456	Remove or replace turbine pumps
5 O 455	Remove or replace steam injector pumps

Total 5

Preliminary
TTM #40

1 X 607	Lubricate pumps
2 X 623	Replace temperature relief valves
3 X 585	Drain storage tanks
4 X 592	Inspect solar heating collectors
5 X 596	Inspect solar heating system pressure relief

TASK NUMBER**TITLE**

valves
6 X 594 Inspect solar heating insulation
7 X 593 Inspect solar heating exterior exchangers
8 X 597 Inspect solar heating transfer fluid system
9 X 598 Inspect transfer fluid pressure relief valves
10 X 595 Inspect solar heating pedestals
11 X 611 Operate solar heating system
12 X 587 Fill solar heating system with transfer fluids
13 X 586 Drain transfer fluids
14 X 620 Replace damaged insulation sections or lengths
15 X 582 Bleed solar heating systems
16 X 599 Install or replace components or solar heating system controls
17 X 588 Flush solar heating systems
18 X 603 Isolate solar heating collector malfunctions
19 X 605 Isolate solar heating pump malfunctions
20 X 606 Isolate solar heating system control malfunctions
21 X 604 Isolate solar heating heat exchanger malfunctions
22 X 615 Remove or replace solar heating system pressure relief valves
23 X 626 Service solar heating collectors
24 X 609 Measure solar heating system piping
25 X 610 Measure solar heating system pressures
26 X 608 Measure flow rates
27 X 617 Repair solar heating collectors
28 X 616 Repair solar heating collector racks
29 X 614 Regulate operational pressures
30 X 622 Replace solar heating exterior heat exchangers
31 X 618 Repair solar heating exterior heat exchangers
32 X 613 Perform solar heating system hydrostatic tests
33 X 581 Adjust solar heating system panels
34 X 583 Calibrate solar heating system controls
35 X 601 Install or replace solar heating collectors
36 X 600 Install or replace solar heating collector racks
37 X 602 Install or replace solar heating storage tanks
38 X 589 Inspect anode rods
39 X 619 Replace anode rods
40 X 612 Perform expansion tank air pressure checks
41 X 590 Inspect float vent caps
42 X 591 Inspect ion filters

TASK NUMBER

TITLE

43 X 627	Test glycol ph
44 X 630	Tighten pedestal racks
45 X 625	Service pedestals
46 X 628	Test solar heating collector locations
47 X 629	Test transfer fluid specific gravity
48 X 621	Replace ion filters

Total 48

Preliminary
TTM #41

1 F 171	Install solid fuel burners
2 F 156	Install oil separators
3 F 160	Install precipitators
4 F 169	Install solar heating systems
5 F 178	Install superheaters

Total 5

Preliminary
TTM #42

1 L 337	Adjust solid fuel burner fuel-air ratios
2 L 346	Inspect solid fuel burners
3 L 355	Perform solid fuel burner operational checks
4 L 359	Remove or replace solid fuel burners
5 L 349	Lubricate solid fuel burners

Total 5

Preliminary
TTM #43

1 T 527	Monitor central steam plant electrostatic precipitators
2 T 528	Monitor central steam plant mechanical pollution collectors
3 S 492	Clean electrostatic precipitators
4 S 519	Service mechanical pollution collectors

Total 4

Preliminary
TTM #44

TASK NUMBER**TITLE**

1 G 198	Remove or replace coal burning equipment
2 L 350	Perform ash-handling equipment preventive maintenance
3 F 130	Install coal-burning equipment
4 U 534	Inspect coal-handling equipment
5 U 533	Collect coal samples for analyses
6 U 536	Maintain coal storage areas
7 U 535	Inspect coal shipments
8 U 537	Prepare coal sample for analyses

Total 8

Preliminary
TTM #45

1 L 343	Inspect oil pre-heaters
2 L 336	Adjust oil-preheaters
3 L 358	Remove or replace oil pre-heaters
4 F 154	Install oil pre-heaters
5 T 529	Monitor oil pre-heaters
6 S 511	Rebuild oil pre-heaters

Total 6

Preliminary
TTM #46

1 F 174	Install steam fans
2 F 181	Install turbine pumps
3 F 176	Install steam injector pumps
4 K 290	Clean oil separators
5 K 322	Remove or replace oil separators
6 K 324	Remove or replace precipitators

Total 6

**APPENDIX C: TDS FINAL CLUSTERS (TTMs)
545X2 (HEATING SYSTEM SPECIALIST)**

Cluster #	# of Tasks	Name
1	24	Pipe Fitting
2	10	Centrifugal Pumps
3	40	Electrical Components and Controls
4	47	Warm Air Heating Systems
5	52	Steam Heating Systems
6	10	Gas Burning Systems
7	22	Fuel Oil Systems
8	28	Low/Medium Hot Water Heating Systems
9	3	Soldering and Welding
10	4	Electronic Controls
11	15	Pneumatic Systems
12	21	Water Treatment
13	76	Central Steam Plants
14	33	High Temp. Hot Water Heating System
15	47	Solar Heating Systems
16	20	Coal Burning Systems
17	1	Asbestos Removal
TOTAL	= 453	

TASK NUMBER**TITLE****TTM #1****Title: Pipe Fitting**

1	G	207	Thread pipe by machine
2	G	194	Measure and cut pipe by machine
3	G	193	Measure and cut pipe by hand
4	G	206	Thread pipe by hand
5	G	192	Measure and cut copper tubing
6	K	312	Remove or replace check valves
7	K	317	Remove or replace gauges
8	G	195	Measure and cut pre-formed insulation
9	K	291	Clean strainers
10	K	238	Remove or replace strainers
11	K	320	Remove or replace insulating materials on pipes other than asbestos insulation
12	F	157	Install packing
13	F	126	Install check valves
14	F	145	Install gauges
15	F	120	Install black iron steam condensate lines
16	M	403	Remove or replace black iron steam condensate lines
17	F	175	Install steam heating system valves or fittings
18	F	135	Install distribution lines
19	G	196	Mix and apply powdered insulation
20	F	159	Install pre-formed insulation
21	F	151	Install insulating materials on pipes other than pre-formed
22	M	416	Remove or replace thermosetting resin pipe
23	X	620	Replace damaged insulation section or lengths
24	G	189	Lubricate copper tubing systems

TOTAL 24**TTM #2****Title: Centrifugal Pumps**

1	K	311	Remove or replace centrifugal water pumps
2	K	323	Remove or replace packing on centrifugal water pumps
3	K	321	Remove or replace mechanical water pump seals

TASK NUMBER**TITLE**

4	F	129	Install circulating pumps
5	F	138	Install feed or condensate pumps
6	F	125	Install centrifugal water pumps
7	K	297	Inspect centrifugal water pump operations
8	K	277	Adjust centrifugal water pump
9	Q	472	Remove or replace circulating pumps
10	S	515	Remove or replace central steam plant boiler feed and condensate pump

TOTAL 10

TTM #3

Title: Electrical Components and Controls

1	F	152	Install motor starters
2	I	260	Test motor running or starting windings
3	I	261	Test starting or running capacitors
4	F	179	Install timers
5	I	250	Remove or replace circuit breakers
6	I	258	Reset circuit breakers
7	I	252	Remove or replace fuses
8	I	251	Remove or replace electric motors
9	I	243	Inspect fuses or circuit breakers
10	I	263	Wire-in motors to power sources
11	H	208	Adjust electrical thermostats or pressure switches
12	H	227	Remove or replace automatic heating controls or thermostats
13	H	229	Remove or replace electrical controls
14	H	230	Remove or replace electrical wiring on controls
15	F	136	Install electrical motors
16	F	161	Install pressure controls
17	F	119	Install aquastats
18	K	325	Remove or replace solenoid valves
19	F	170	Install solenoid valves
20	I	257	Remove or replace transformers
21	F	180	Install transformers
22	F	137	Install electrical controls
23	I	254	Remove or replace relays
24	F	165	Install relays
25	I	259	Reset motor thermal overloads
26	H	236	Remove or replace pressure potentiometers
27	F	162	Install pressure potentiometers
28	H	239	Test safety control operations

TASK NUMBER**TITLE**

29	I	248	Isolate electrical systems malfunction
30	I	241	Inspect electrical circuits
31	I	242	Inspect electrical power suppliers
32	I	249	Measure motor current draw
33	I	262	Test transformers
34	H	226	Isolate electrical control malfunctions
35	H	216	Calibrate electrical thermostats or pressure switches
36	H	219	Calibrate motorized valves
37	I	253	Remove or replace motor starters
38	I	245	Inspect starting or running capacitors
39	I	255	Remove or replace starting or running capacitors
40	F	173	Install starting or running capacitors

Total 40

TTM #4

Title: Warm Air Heating Systems

1	K	229	Adjust couplings or pulleys
2	K	284	Align couplings or pulleys
3	K	281	Adjust drive belts
4	K	285	Align drive belts
5	K	280	Adjust dampers
6	K	298	Inspect dampers
7	K	302	Lubricate fans
8	K	301	Lubricate air handling equipment
9	G	191	Lubricate heating blowers
10	G	201	Remove or replace heating blowers
11	G	190	Inspect heat exchangers
12	G	186	Clean heat exchangers
13	F	132	Install couplings or pulleys
14	F	141	Install fitters
15	K	310	Remove or replace burners in forced heating systems
16	K	315	Remove or replace electrical fans
17	K	282	Adjust valve and damper linkages
18	K	329	Remove or replace valve and damper linkages
19	F	183	Install valve or damper linkages
20	G	205	Remove or replace unit heaters
21	F	182	Install unit heaters
22	G	204	Remove or replace space heaters
23	F	172	Install space heaters
24	G	199	Remove or replace furnaces
25	F	142	Install furnaces

TASK NUMBER**TITLE**

26	F	148	Install heating blowers
27	G	200	Remove or replace heat exchangers
28	F	147	Install heat exchangers
29	F	150	Install insulating materials on ducts other than pre-formed insulation
30	K	293	Inspect and clean ducts
31	K	295	Inspect and clean fresh air supply systems
32	G	187	Connect exhaust outlets to flues or stacks
33	G	188	Connect heating outlets to ducts
34	H	224	Inspect reheating systems
35	F	149	Install humidistats
36	H	211	Adjust humidity equipment other than humidistats
37	K	303	Measure airflow or pressure with manometers
38	K	304	Measure airflow with anemometers
39	K	305	Measure airflow with velometers
40	K	316	Remove or replace fitters
41	K	294	Inspect and clean filters
42	K	300	Inspect motor or fan bearings
43	K	299	Inspect drive belts
44	K	289	Clean and lubricate motor or fan bearings

TOTAL 44**TTM #5****Title: Steam Heating Systems**

1	M	395	Insulate low pressure steam heating system combustion chamber doors
2	M	408	Remove or replace low pressure steam heating combustion chamber doors
3	M	417	Trace steam distribution systems
4	M	391	Inspect steam traps
5	M	390	Inspect steam lines or conduits
6	M	378	Inspect condensate lines or conduits
7	N	422	Lowdown steam heating system boilers or water columns
8	N	424	Light-off steam heating system boilers
9	N	426	Perform steam heating system boiler pre-operational checks
10	M	382	Inspect steam heating system boiler feed and condensate pumps
11	M	384	Inspect steam heating system boiler

TASK NUMBERTITLE

12	M	385	manhole and handhole covers Inspect steam heating system boiler safety valves
13	M	386	Inspect steam heating system combustion chambers
14	M	373	Drain steam heating system boilers
15	M	375	Fill steam heating system boilers
16	M	409	Remove or replace steam heating system boiler gauge glasses
17	M	410	Remove or replace steam heating system boiler manhole or handhole cover gaskets
18	M	368	Clean steam heating system boiler gauge glasses
19	M	369	Clean steam heating system boiler tubes
20	M	377	Inspect and wash down steam heating system boiler water sides
21	M	361	Clean and inspect steam heating system combustion chambers
22	N	423	Check steam heating system boiler tricocks
23	M	381	Inspect fire tubes for leaks or spot build-up
24	M	380	Inspect feed water controls (Mcdonnell-Miller)
25	M	363	Clean feed water controls (Mcdonnell-Miller)
26	M	407	Remove or replace feed water controls (Mcdonnell-Miller)
27	M	413	Remove or replace steam heating system pressure relief valves
28	M	414	Remove or replace steam heating system safety valves
29	M	411	Remove or replace steam heating system boiler feed or condensate pumps
30	M	415	Remove or replace steam heating system valves or fittings other than safety or pressure relief
31	M	392	Inspect water tubes for leaks
32	N	420	Adjust steam heating system feed water regulators
33	N	421	Adjust steam heating system steam regulating valves
34	M	374	Drain steam system other than boilers
35	N	425	Perform steam heating system boiler draft control operational checks
36	N	427	Perform steam heating system

TASK NUMBERTITLE

37	M	370	combustion efficiency analyses
38	M	398	Clean tube sheets
39	M	396	Perform steam heating system refractory repairs
40	M	400	Isolate steam heating system boiler flame control malfunctions
41	M	399	Rebuild steam traps
42	M	388	Rebuild feed water controls (Mcdonnell-Miller)
43	F	121	Inspect steam heating system expansion joints
44	F	122	Install boiler gauge glasses
45	F	163	Install boiler safety valves
46	F	167	Install pressure regulating valves (PRU)
47	F	140	Install safety controls
48	F	139	Install feedwater regulators
49	G	197	Install feedwater controls
50	F	123	Remove or replace boilers
51	M	259	Install boilers
52	M	405	Inspect and clean steam heating system smokestacks
			Remove or replace boiler safety valves

TOTAL 52

TTM #6

Title: Gas Burning Systems

1	L	340	Inspect gas burners
2	L	334	Adjust gas burner fuel-air ratios
3	L	351	Perform gas burner operational checks
4	L	356	Remove or replace gas burners
5	F	144	Install gas burners
6	L	341	Inspect liquid petroleum tanks
7	L	352	Perform liquid petroleum tank preventive maintenance
8	L	347	Lubricate gas burners
9	W	576	Remove or replace interior gas service lines
10	W	572	Read meters

TOTAL 10

TTM #7

Title: Fuel Oil Systems

1	L	339	Inspect fuel lines or fittings
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TASK NUMBERTITLE

2	L	342	Inspect oil burners
3	L	335	Adjust oil burner fuel-air ratios
4	L	353	Perform oil burner operational checks
5	L	357	Remove or replace oil burners
6	L	360	Verify quantity of fuel oil in tanks
7	L	344	Inspect oil storage tanks
8	L	345	Inspect oil tanks for water or other impurities
9	L	348	Lubricate oil burners
10	F	153	Install oil burners
11	L	354	Perform oil storage tank preventive maintenance
12	L	343	Inspect oil pre-heaters
13	L	336	Adjust oil pre-heaters
14	L	358	Remove or replace oil pre-heaters
15	F	154	Install oil pre-heaters
16	T	529	Monitor oil pre-heaters
17	S	511	Rebuild oil pre-heaters
18	F	166	Install rotary positive displacement pumps
19	H	235	Remove or replace oil safety switches
20	F	155	Install oil safety switches
21	H	220	Calibrate oil safety switches
22	O	454	Remove or replace rotary positive displacement pumps

TOTAL 22

TTM #8

Title: Low/Medium Hot Water Heating Systems

1	R	478	Fill low or medium temperature water heating systems with water and bleed air from systems
2	R	477	Drain or flush low or medium temperature water heating system boilers
3	R	479	Inspect low or medium temperature water heating system boilers for leaks
4	R	481	Light-off or medium temperature water heating system boilers
5	R	485	Perform low or medium temperature water heating system operational checks
6	R	483	Perform low or medium temperature water heating system boiler pre-operational checks

TASK NUMBERTITLE

7	R	482	Perform aquastat operational checks
8	R	480	Lay up low or medium temperature water heating system boilers
9	O	467	Inspect low or medium temperature water heating system pressure relief valves
10	O	465	Clean low or medium temperature water heating system boilers
11	O	475	Remove or replace low or medium temperature water heating system pressure relief valves
12	Q	476	Remove or replace pressure regulating valves
13	Q	473	Remove or replace low or medium temperature water heating air bleed valves
14	Q	474	Remove or replace low or medium temperature water heating system distribution lines
15	Q	471	Remove or replace aquastats
16	Q	468	Isolate low or medium temperature hot water heating system boiler flame control malfunctions
17	Q	469	Isolate one or two pipe water heating system malfunctions
18	Q	466	Clean one or two pipe water heating systems
19	Q	470	Perform low or medium temperature water heating system refractory repair
20	R	486	Recharge low or medium temperature water heating system closed expansion tanks
21	P	484	Perform low or medium temperature water heating system combustion efficiency analyses
22	K	283	Adjust water regulating valves
23	K	330	Remove or replace water regulating valves
24	F	184	Install water regulating valves
25	F	118	Install air bleed valves
26	H	215	Analyze pressure or temperature readings
27	F	168	Install safety valves other than boiler safety valves
28	G	203	Remove or replace sectional boiler sections

TOTAL 28

TASK NUMBERTITLE

TTM #9

Title: Soldering and Welding

1	K	333	Silver solder lines or fittings
2	K	306	Oxyacetylene weld lines, bracings, or fittings
3	K	236	Arc weld lines, bracings, or fittings

TOTAL 3

TTM #10

Title: Electronic Controls

1	H	209	Adjust electronic controls
2	H	232	Remove or replace electronic controls
3	H	231	Remove or replace electronic control components
4	H	217	Calibrate electronic controls

TOTAL 4

TTM #11

Title: Pneumatic Systems

1	J	269	Blowdown condensate from air tanks
2	J	272	Inspect compressor oil levels
3	J	271	Clean and lubricate compressors
4	J	264	Adjust air compressor belts
5	J	268	Align air compressor belts
6	J	265	Adjust air compressor pressure controls
7	F	158	Install pneumatic controls
8	J	267	Adjust pressure regulators
9	J	276	Remove or replace pressure controls
10	J	266	Adjust pneumatic controls
11	J	275	Remove or replace pneumatic controls
12	J	273	Isolate pneumatic control malfunctions
13	J	270	Calibrate pneumatic controls
14	J	274	Perform pneumatic safety valve operational checks
15	K	307	Perform adjustments at control panels to remotely reposition control devices

TOTAL 15

TTM #12

Title: Water Treatment

TASK NUMBERTITLE

1	V	539	Draw boiler water samples
2	V	543	Mix chemicals required to treat water
3	V	541	Inspect chemical reagents and test equipment
4	V	542	Maintain boiler chemical storage areas
5	E	107	Make entries on AF Forms 1459 (water treatment operating log for steam and hot water boilers)
6	K	313	Remove or replace chemical feeding equipment
7	F	127	Install chemical feeding equipment
8	M	387	Inspect steam heating system deaerators
9	N	419	Adjust steam heating system deaerators
10	M	379	Inspect demineralizers or water softeners
11	M	372	Drain demineralizers or water softeners
12	M	397	Perform demineralizer or water softener operational checks
13	N	418	Adjust demineralizers or water softeners
14	V	544	Monitor demineralizers or water softeners
15	V	538	Clean demineralizers or water softeners
16	N	428	Test brine solution
17	V	547	Recharge demineralizers
18	F	131	Install corrosion testers
19	O	448	Remove or replace corrosion testers in distribution lines
20	O	457	Submit corrosion testers for analysis

TOTAL 20

TTM #13

Title: Central Steam Plants

1	M	364	Clean mud drums
2	M	366	Clean steam drums
3	E	106	Make entries on AF Form 1458
4	E	108	Make entries on AF Form 1464
5	F	164	Install reciprocating pumps
6	M	389	Inspect steam heating system steam indicating and recording equipment
7	S	487	Clean and lubricate central steam plant steam indicating and recording

TASK NUMBERTITLE

8	S	488	equipment Clean central steam plant boiler airflow switches
9	T	521	Blowdown central steam plant boiler or water columns
10	T	522	Check central steam plant boiler water level
11	T	526	Light-off central steam plant boilers
12	T	523	Drain central steam plant boilers
13	T	530	Perform central steam plant boiler pre-operational checks
14	T	525	Lay up central steam plant boilers wet
15	S	509	Prepare boilers for inspections
16	S	499	Inspect central steam plant boiler manhole and handhole covers
17	S	497	Inspect central steam plant boiler feed and condensate pumps
18	S	493	Fill central steam plant boilers and check for leaks
19	S	513	Remove or replace central steam plant boiler manhole and handhole cover gaskets
20	S	514	Remove or replace central steam plant boiler gauge glasses
21	S	489	Clean central steam plant boiler gauge glasses
22	S	490	Clean central steam plant boiler tubes
23	S	496	Inspect and wash down central steam plant boiler water sides
24	S	500	Inspect central steam plant combustion chambers
25	S	494	Inspect and clean central steam plant combustion chambers
26	S	503	Inspect feed water regulators
27	S	517	Remove or replace central steam plant valves or fittings other than safety or pressure relief
28	S	516	Remove or replace central steam plant safety valves
29	S	512	Regulate steam output of boilers
30	S	505	Perform automatic boiler control operational checks
31	S	506	Perform central steam plant boiler draft control operational checks
32	S	504	Isolate central steam plant boiler flame control malfunctions
33	S	508	Perform central steam plant refractory

TASK NUMBERTITLE

34	T	532	repair Perform corrective action in case of boiler safety shutdowns
35	T	531	Perform central steam plant combustion efficiency analyses
36	T	520	Adjust central steam plant regulating valves
37	S	502	Inspect central steam plant steam indicating and recording equipment
38	S	501	Inspect central steam plant deaerators
39	S	491	Clean central steam plant deaeration equipment
40	S	507	Perform central steam plant boiler or expansion tank hydrostatic tests
41	S	510	Rebuild feed water regulators
42	S	495	Inspect and clean central steam plant smokestacks
43	T	524	Lay up central steam plant boilers dry
44	S	498	Inspect central steam plant boiler fusible plugs
45	S	518	Remove or replace fusible plugs
46	M	383	Inspect steam heating system boiler fusible plugs
47	M	404	Remove or replace boiler fusible plugs
48	F	148	Install fusible plugs
49	H	222	Clean and service central heating plant control panels
50	H	225	Isolate central heating plant malfunctions
51	H	228	Remove or replace central heating plant control panel components
52	H	124	Install central heating plant control panels
53	F	134	Install demineralizers or water softeners
54	M	406	Remove or replace demineralizers or water softeners
55	M	362	Clean and lubricate steam heating systems steam indicating and recording equipment
56	M	367	Clean steam heating system boiler airflow switches
57	M	365	Clean new tube ends with emery cloth
58	O	456	Remove or replace turbine pumps
59	O	455	Remove or replace steam injector pumps
60	F	133	Install deaerators
61	O	453	Remove or replace reciprocating pumps
62	M	371	Cut tubes to prescribed length

TASK NUMBERTITLE

63	M	402	Remove damaged tubes
64	M	394	Install new tubes with rolling device
65	M	393	Install new tubes by hand
66	M	412	Remove or replace steam heating system deareators. Remove or replace steam or temperature recording equipment
67	F	174	install steam or temperature recording equipment
67	F	174	Install steam fans
68	F	181	Install turbine pumps
69	F	176	Install steam injector pumps
70	K	290	Clean oil separators
71	K	322	Remove or replace oil separators
72	F	156	Install oil separators
73	F	178	Install superheaters
74	F	177	Install steam or temperature recording equipment
75	K	327	Remove or replace steam or temperature recording equipment

TOTAL 75

TTM #14

Title: High Temperature Hot Water Heating Systems

1	O	439	Inspect safety valves
2	O	435	Inspect high temperature water heating system boilers for leaks
3	O	436	Inspect high temperature water heating system pressure relief valves
4	O	434	Inspect high temperature water heating distribution systems
5	O	433	Fill high temperature water heating systems with water and bleed air from systems
6	O	432	Drain or flush high temperature water heating system boilers
7	O	430	Clean high temperature water heating system boilers
8	O	437	Inspect high temperature water heating system conduits
9	O	438	Inspect pressurization systems
10	P	462	Perform high temperature water heating system operational checks
11	P	459	Light-off high temperature water heating systems
12	P	460	Perform high temperature water heating system boiler pre-operational checks

TASK NUMBERTITLE

13	P	463	Perform high temperature water heating system control valve operational checks
14	P	461	Perform high temperature water heating system combustion efficiency analyses
15	P	458	Adjust high temperature water heating system regulating valves
16	O	451	Remove or replace high temperature water heating system safety valves
17	O	452	Remove or replace high temperature water pressure relief valves
18	O	450	Remove or replace high temperature water heating system centrifugal water pumps
19	O	449	Remove or replace high temperature water heating system air bleed valves
20	O	443	Lubricate high temperature water heating system control valves
21	O	441	Isolate high temperature water heating system boiler flame control malfunctions
22	O	442	Lay up high temperature water heating system boilers
23	O	447	Perform high temperature water heating system refractory repairs
24	O	446	Perform high temperature water heating system boiler or expansion tank hydrostatic tests
25	O	440	Inspect temperature recording equipment
26	O	431	Clean temperature recording equipment
27	P	464	Recharge high temperature water heating system closed expansion tanks
28	O	445	Pack or lubricate high temperature water heating system expansion joints
29	O	429	Align high temperature water heating system expansion joints
30	E	105	Make entries on AF Forms 1165 (monthly high temperature water plan operating log)
31	E	104	Make entries on AF Forms 1163 (monthly high temperature water distribution system operating log)
32	O	444	Lubricate temperature recording equipment
33	F	146	Install generator or system pumps

TOTAL 33

TASK NUMBER**TITLE**

TTM #15

Title: Solar Heating Systems

1	X	607	Lubricate pumps
2	X	623	Replace temperature relief valves
3	X	585	Drain storage tanks
4	X	592	Inspect solar heating collectors
5	X	596	Inspect solar heating system pressure relief valves
6	X	594	Inspect solar heating insulation
7	X	5593	Inspect solar heating exterior heat exchanges
8	X	597	Inspect solar heating transfer fluid systems
9	X	598	Inspect transfer fluid pressure relief valves
10	X	595	Inspect solar heating pedestals
11	X	611	Operate solar heating systems
12	X	587	Fill solar heating systems with transfer fluids
13	X	586	Drain transfer fluids
14	X	582	Bleed solar heating systems
15	X	599	Install or replace components of solar heating systems controls
16	X	588	Flush solar heating systems
17	X	603	Isolate solar heating collector malfunctions
18	X	605	Isolate solar heating pump malfunctions
19	X	606	Isolate solar heating systems control malfunctions
20	X	604	Isolate solar heating heat exchanger malfunctions
21	X	615	Remove or replace solar heating system pressure relief valves
22	X	626	Service solar heating collectors
23	X	609	Measure solar heating system piping
24	X	610	Measure solar heating system pressures
25	X	608	Measure flow rates
26	X	617	Repair solar heating collectors
27	X	614	Regulate operational pressures
28	X	622	Replace solar heating exterior heat exchangers
29	X	618	Repair solar heating exterior heat exchangers
30	X	613	Perform solar heating system hydrostatic tests
31	X	581	Adjust solar heating system panels

TASK NUMBER**TITLE**

32	X	583	Calibrate solar heating system controls
33	X	601	Install or replace solar heating collectors
34	X	600	Install or replace solar heating collector racks
35	X	602	Install or replace solar heating storage tanks
36	X	589	Inspect anode rods
37	X	619	Replace anode rods
38	X	612	Perform expansion tank air pressure checks
39	X	590	Inspect float vent caps
40	X	591	Inspect ion filters
41	X	627	Test glycol ph
42	X	630	Tighten pedestal racks
43	X	625	Service pedestals
44	X	628	Test solar heating collector locations
45	X	629	Test transfer fluid specific gravity
46	X	621	Replace ion filters
47	F	169	Install solar heating systems

TOTAL 47

TTM #16

Title: Coal Burning Systems

1	L	337	Adjust solid fuel burner fuel-air ratios
2	L	346	Inspect solid fuel burners
3	L	355	Perform solid fuel burner operational checks
4	L	359	Remove or replace solid fuel burners
5	L	349	Lubricate solid fuel burners
6	F	171	Install solid fuel burners
7	F	169	Install precipitators
8	T	527	Monitor central steam plant electrostatic precipitators
9	T	528	Monitor central steam plant mechanical pollution collector
10	S	492	Clean electrostatic precipitators
11	S	519	Service mechanical pollution collectors
12	G	198	Remove or replace coal burning equipment
13	L	350	Perform ash handling equipment preventive maintenance
14	F	130	Install coal burning equipment
15	4	534	Inspect coal handling equipment
16	4	533	Collect coal samples for analysis

TASK NUMBER

TITLE

17	4	536	Maintain coal storage areas
18	4	535	Inspect coal shipments
19	4	537	Prepare coal samples for analysis
20	K	324	Remove or replace precipitators

TOTAL 20

TTM #17

Title: Asbestos Removal

1	K	309	Remove asbestos insulation in ducts or pipes
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TOTAL 1

APPENDIX D. OMT PRELIMINARY CLUSTERS (TMs)*
AFS 545X2
(HEATING SYSTEM SPECIALIST)

Cluster	# of Tasks	Name
1	67	Installing New Heating Systems and Equipment
2	39	Maintaining Forced Warm Air Systems
3	16	Maintaining Heating Control Systems
4	27	Maintaining High Temperature Water Heating Systems
5	9	Operating High Temperature Water Heating Systems
6	10	Performing Water Treatment Functions
7	47	Maintaining Solar Heating Systems
8	3	Fabricating Copper Tubing Systems
9	6	Fabricating Piping Systems
10	1	Insulating Piping System With Pre-formed Insulation
11	2	Insulating Piping System With Other Than Preformed Insulation
12	29	Operating & Maintaining Low and Medium Temperature Water Heating Systems
13	35	Maintaining Central Steam Plant
14	20	Operating Central Steam Plants
15	18	Maintaining Pneumatic Systems
16	18	Maintaining Heating Electrical Systems
17	10	Operating Steam Heating Systems
18	62	Maintaining Steam Heating Systems
19	9	Operating Fuel Burning Equipment and Area
20	25	Maintaining Fuel Burning Equipment and Area

TOTAL = 453

* OMT clusters are often referred to as Task Modules (TMs).

TASK NUMBER**TITLE**

TM #1

Title: INSTALLING NEW HEATING SYSTEMS AND EQUIPMENT

1	F-118	Install air bleed valves
2	F-119	Install aquastats
3	F-120	Install black iron steam condensate lines
4	F-121	Install boiler gauge glasses
5	F-122	Install boiler safety valves
6	F-123	Install boilers
7	F-124	Install central heating plant control panels
8	F-125	Install centrifugal water pumps
9	F-126	Install check valves
10	F-127	Install chemical feeding equipment
11	F-128	Install circuit breakers
12	F-129	Install circulating pumps
13	F-130	Install coal-burning equipment
14	F-131	Install corrosion testers
15	F-132	Install couplings or pulleys
16	F-133	Install deaerators
17	F-134	Install demineralizers or water softeners
18	F-135	Install distribution lines
19	F-136	Install electric motors
20	F-137	Install electrical controls
21	F-138	Install feed or condensate pumps
22	F-139	Install feed water controls
23	F-140	Install feed water regulators
24	F-141	Install filters
25	F-142	Install furnaces
26	F-143	Install fusible plugs
27	F-144	Install gas burners
28	F-145	Install gauges
29	F-146	Install generator or system pumps
30	F-147	Install heat exchangers
31	F-148	Install heating blowers
32	F-149	Install humidistats
33	F-150	Install insulating materials on ducts other than pre-formed insulation
34	F-151	Install insulation materials on pipes other than pre-formed insulation
35	F-152	Install motor starters
36	F-153	Install oil burners
37	F-154	Install oil pre-heaters
38	F-155	Install oil safety switches
39	F-156	Install oil separators
40	F-157	Install packing
41	F-158	Install pneumatic controls

TASK NUMBERTITLE

42	F-159	Install pre-formed insulation
43	F-160	Install precipitators
44	F-161	Install pressure controls
45	F-162	Install potentiometers
46	F-163	Install pressure regulating valves (PRV)
47	F-164	Install reciprocating pumps
48	F-165	Install relays
49	F-166	Install rotary positive displacement pumps
50	F-167	Install safety controls
51	F-168	Install safety valves other than boiler safety valves
52	F-169	Install solar heating systems
53	F-170	Install solenoid valves
54	F-171	Install solid fuel burners
55	F-172	Install space heaters
56	F-173	Install starting or running capacitors
57	F-174	Install steam powered fans
58	F-175	Install steam heating system valves or fittings
59	F-176	Install steam injector pumps
60	F-177	Install steam or temperature recording equipment
61	F-178	Install superheaters
62	F-179	Install timers
63	F-180	Install transformers
64	F-181	Install turbine pumps
65	F-182	Install unit heaters
66	F-183	Install valve or damper linkages
67	F-184	Install water regulating valves

TM #2

Title: MAINTAINING FORCED WARM AIR SYSTEMS

1	G-186	Clean heat exchangers
2	G-187	Connect exhaust outlets to flues or stacks
3	G-188	Connect heating outlets to ducts
4	G-190	Inspect heat exchangers
5	G-191	Lubricate heating blowers
6	G-199	Remove or replace furnaces
7	G-200	Remove or replace heat exchangers
8	G-201	Remove or replace heating blowers
9	G-204	Remove or replace space heaters
10	G-205	Remove or replace unit heaters
11	K-279	Adjust couplings or pulleys
12	K-280	Adjust dampers
13	K-281	Adjust drive belts
14	K-282	Adjust valve and damper linkages

TASK NUMBERTITLE

15	K-283	Adjust water pressure regulating valves
16	K-284	Align couplings or pulleys
17	K-285	Align drive belts
18	K-288	Clean and lubricate blower bearings
19	K-289	Clean and lubricate motor or fan bearings
20	K-293	Inspect and clean ducts
21	K-294	Inspect and clean filters
22	K-295	Inspect and clean fresh air supply systems
23	K-296	Inspect blower bearings
24	K-298	Inspect dampers
25	K-299	Inspect drive belts
26	K-300	Inspect motor or fan bearings
27	K-301	Lubricate air handling units
28	K-302	Lubricate fans
29	K-303	Measure airflow or pressure with manometers
30	K-304	Measure airflow with anemometers
31	K-305	Measure airflow with anemometers
32	K-309	Remove asbestos insulation on ducts or pipes
33	K-310	Remove or replace burners in forced air heating systems
34	K-314	Remove or replace couplings or pulleys
35	K-315	Remove or replace electrical fans
36	K-316	Remove or replace filters
37	K-317	Remove or replace gauges
38	K-325	Remove or replace solenoid valves
39	K-329	Remove or replace valve and damper linkages

TM #3

Title: MAINTAINING HEATING CONTROL SYSTEMS

1	H-208	Adjust electrical thermostats or pressure switches
2	H-209	Adjust electronic controls
3	H-216	Calibrate electrical thermostats or pressure switches
4	H-217	Calibrate electronic controls
5	H-219	Calibrate motorized valves
6	H-225	Isolate central heating plant control panel malfunctions
7	H-226	Isolate electrical control malfunctions
8	H-227	Remove or replace automatic heating controls or components
9	H-228	Remove or replace central heating plant control panel components
10	H-229	Remove or replace electrical controls
11	H-230	Remove or replace electrical wiring on controls

TASK NUMBERTITLE

12	H-231	Remove or replace electronic control components
13	H-232	Remove or replace electronic controls
14	H-236	Remove or replace pressure potentiometers
15	H-239	Test safety control operations
16	K-307	Perform adjustments at control panels to remotely reposition control devices

TM #4

Title: MAINTAINING HIGH TEMPERATURE WATER HEATING SYSTEMS

1	0-429	Align high temperature water heating system expansion joints
2	0-430	Clean high temperature water heating system boilers
3	0-431	Clean temperature recording equipment
4	0-432	Drain or flush high temperature water heating system boilers
5	0-433	Fill high temperature water heating systems with water and bleed air from systems
6	0-434	Inspect high temperature water heating distribution systems
7	0-435	Inspect high temperature water heating system boilers for leaks
8	0-436	Inspect high temperature water heating system pressure relief valves
9	0-437	Inspect high temperature water heating system conduits
10	0-438	Inspect pressurization systems
11	0-439	Inspect safety valves
12	0-440	Inspect temperature recording equipment
13	0-441	Isolate high temperature water heating system boiler flame control malfunctions
14	0-442	Lay up high temperature water heating system boilers
15	0-443	Lubricate high temperature water heating system control valves
16	0-444	Lubricate temperature recording equipment
17	0-445	Pack or lubricate high temperature water heating system expansion joints
18	0-446	Perform high temperature water heating system boilers or expansion tank hydrostatic tests
19	0-447	Perform high temperature water heating system refractory repairs
20	0-449	Remove or replace high temperature water heating system air bleed valves
21	0-450	Remove or replace high temperature water

TASK NUMBERTITLE

22	0-451	heating system centrifugal water pumps Remove or replace high temperature water heating system safety valves
23	0-452	Remove or replace high temperature water pressure relief valves
24	0-453	Remove or replace reciprocating pumps
25	0-454	Remove or replace rotary positive-displacement pumps
26	0-455	Remove or replace steam injector pumps
27	0-456	Remove or replace turbine pumps

TM #5

Title: OPERATING HIGH TEMPERATURE WATER HEATING SYSTEMS

1	P-458	Adjust high temperature water heating system regulating valves
2	P-459	Light-off high temperature water heating systems
3	P-460	Perform high temperature water heating system boiler pre-operational checks
4	P-461	Perform high temperature water heating system combustion efficiency analysis
5	P-462	Perform high temperature water heating system operational checks
6	P-463	Perform high temperature water heating system control valve operational checks
7	P-464	Recharge high temperature water heating system closed expansion tanks
8	E-104	Make entries on AF Form 1163 (Monthly High Temperature Water Distribution System Operating Log)
9	E-105	Make entries on AF Forms 1165 (Monthly High Temperature Water Plant Operating Log)

TM #6

Title: PERFORMING WATER TREATMENT FUNCTIONS

1	V-539	Draw boiler water samples
2	V-540	Draw condensate return water samples
3	V-541	Inspect chemical reagent and test equipment
4	V-542	Maintain boiler chemical storage areas
5	V-543	Mix chemicals required to treat water
6	V-549	Test boiler water for chlorides or total dissolved solids
7	E-107	Make entries on AF Forms 1459 (Water Treatment Operating Log for Steam and Hot Water Boilers)

TASK NUMBERTITLE

8	N-428	Test brine solution
9	O-448	Remove or replace corrosion testers in distribution lines
10	O-457	Submit corrosion testers for analysis

TM #7

Title: MAINTAINING SOLAR HEATING SYSTEMS

1	X-581	Adjust solar heating system panels
2	X-582	Bleed solar heating systems
3	X-583	Calibrate solar heating system controls
4	X-585	Drain storage tanks
5	X-586	Drain transfer fluids
6	X-587	Fill solar heating systems with transfer fluids
7	X-588	Flush solar heating systems
8	X-589	Inspect anode rods
9	X-590	Inspect float vent caps
10	X-591	Inspect ion filter
11	X-592	Inspect solar heating collectors
12	X-593	Inspect solar heating exterior heat exchangers
13	X-594	Inspect solar heating insulation
14	X-595	Inspect solar heating pedestals
15	X-596	Inspect solar heating system pressure relief valves
16	X-597	Inspect solar heating transfer fluid systems
17	X-598	Inspect transfer fluid pressure relief valves
18	X-599	Install or replace components of solar heating system controls
19	X-600	Install or replace solar heating collector racks
20	X-601	Install or replace solar heating collectors
21	X-603	Isolate solar heating collector malfunctions
22	X-625	Service pedestals
23	X-626	Service solar heating collectors
24	X-627	Test glycol pH
25	X-628	Test solar heating collector locations
26	X-629	Test transfer fluid specific gravity
27	X-630	Tighten pedestal racks
28	X-604	Isolate solar heating heat exchanger malfunctions
29	X-605	Isolate solar heating pump malfunctions
30	X-606	Isolate solar heating system control malfunctions
31	X-607	Lubricate pumps
32	X-608	Measure flow rates
33	X-609	Measure solar heating system piping

TASK NUMBERTITLE

34	X-610	Measure solar heating system pressures
35	X-611	Operate solar heating systems
36	X-612	Perform expansion tank air pressure checks
37	X-613	Perform solar heating system hydrostatic tests
38	X-614	Regulate operational pressures
39	X-615	Remove or replace solar heating system pressure relief valves
40	X-616	Repair solar heating collector racks
41	X-617	Repair solar heating collectors
42	X-618	Repair solar heating exterior heat exchangers
43	X-619	Replace anode rods
44	X-620	Replace damaged insulation sections or lengths
45	X-621	Replace ion filters
46	X-622	Replace solar heating exterior heat exchangers
47	X-623	Replace temperature relief valves

TM #8

Title: FABRICATING COPPER TUBING SYSTEMS

1	G-189	Fabricate copper tubing systems
2	G-192	Measure and cut copper tubing
3	K-333	Silver solder lines or fittings

TM #9

Title: FABRICATING PIPING SYSTEMS

1	G-193	Measure and cut pipe by hand
2	G-194	Measure and cut pipe by machine
3	G-206	Thread pipe by hand
4	G-207	Thread pipe by machine
5	K-286	Arc weld lines, bracings, or fittings
6	K-306	Oxyacetylene weld lines, bracings or fittings

TM #10

Title: INSULATING PIPING SYSTEM WITH PRE-FORMED INSULATION

1	G-195	Measure and cut pre-formed insulation
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TM #11

Title: INSULATING PIPING SYSTEM WITH OTHER THAN PRE-FORMED INSULATION

TASK NUMBERTITLE

- | | | |
|---|-------|--|
| 1 | G-196 | Mix and apply powered insulation |
| 2 | K-320 | Remove or replace insulating materials on pipes other than asbestos insulation |

TM #12

Title: OPERATING AND MAINTAINING LOW TEMPERATURE WATER HEATING SYSTEMS

- | | | |
|----|-------|--|
| 1 | Q-465 | Clean low or medium temperature water heating system boilers |
| 2 | Q-466 | Clean one or two pipe water heating systems |
| 3 | Q-467 | Inspect low or medium temperature water heating system pressure relief valves |
| 4 | Q-468 | Isolate low or medium temperature hot water heating system boiler flame control malfunctions |
| 5 | Q-469 | Isolate one or two pipe water heating system malfunctions |
| 6 | Q-470 | Perform low or medium temperature water heating system refractory repair |
| 7 | Q-471 | Remove or replace aquastats |
| 8 | Q-472 | Remove or replace circulating pumps |
| 9 | Q-473 | Remove or replace low or medium temperature water heating air bleed valves |
| 10 | Q-474 | Remove or replace low or medium temperature water heating system distribution lines |
| 11 | Q-475 | Remove or replace low or medium temperature water heating system pressure relief valves |
| 12 | Q-476 | Remove or replace pressure regulating valves |
| 13 | R-477 | Drain or flush low or medium temperature water heating system boilers |
| 14 | R-478 | Fill low or medium temperature water heating systems with water and bleed air from systems |
| 15 | R-479 | Inspect low or medium temperature water heating system boilers for leaks |
| 16 | R-480 | Lay up low or medium temperature water heating system boilers |
| 17 | R-481 | Light-off low or medium temperature water heating system boilers |
| 18 | R-482 | Perform aquastat operational checks |
| 19 | R-483 | Perform low or medium temperature water heating system boiler pre-operation checks |
| 20 | R-484 | Perform low or medium water heating system combustion efficiency analysis |
| 21 | R-485 | Perform low or medium temperature water heating system operational checks |
| 22 | R-486 | Recharge low or medium temperature water |

TASK NUMBERTITLE

		heating system closed expansion tanks
23	K-277	Adjust centrifugal water pump
24	K-297	Inspect centrifugal water pump operations
25	K-311	Remove or replace centrifugal water pumps
26	K-321	Remove or replace mechanical water pump seals
27	K-323	Remove or replace packing on centrifugal water pumps
28	K-328	Remove or replace strainers
29	K-330	Remove or replace water regulating valves

TM #13

Title: MAINTAINING CENTRAL STEAM PLANTS

1	S-487	Clean and lubricate central steam plant steam indicating and recording equipment
2	S-488	Clean central steam plant boiler airflow switches
3	S-489	Clean central steam plant boiler gauge glasses
4	S-490	Clean central steam plant boiler tube
5	S-491	Clean central steam plant deaeration equipment
6	S-492	Clean electrostatic precipitators
7	S-493	Fill central steam plant boilers and check for leaks
8	S-494	Inspect and clean central steam plant combustion chambers
9	S-495	Inspect and clean central steam plant smokestacks
10	S-496	Inspect and wash down central steam plant steam boiler water sides
11	S-497	Inspect central steam plant boiler feed and condensate pumps
12	S-498	Inspect central steam plants boiler fusible plugs
13	S-499	Inspect central steam plant boiler manhole and handhole covers
14	S-500	Inspect central steam plant combustion chambers
15	S-501	Inspect central steam plant deaerators
16	S-502	Inspect central steam plant steam indicating and recording equipment
17	S-503	Inspect feed water regulators
18	S-508	Perform central steam plant refractory repair
19	S-509	Prepare boilers for inspections
20	S-510	Rebuild feed water regulators
21	S-511	Rebuild oil pre-heaters
22	S-513	Remove or replace central steam plant boiler manhole and handhole cover gaskets

TASK NUMBERTITLE

23	S-514	Remove or replace central steam plant boiler gauge glasses
24	S-515	Remove or replace central steam plant boiler feed and condensate pumps
25	S-516	Remove or replace central steam plant safety valves
26	S-517	Remove or replace central steam plant valves or fittings other than safety or pressure relief
27	S-518	Remove or replace fusible plugs
28	S-519	Service mechanical pollution collectors
29	H-222	Clean and service central heating plant control panels
30	T-523	Drain central steam plants boilers
31	T-524	Lay up central steam plant boilers dry
32	T-525	Lay up central steam plant boilers wet
33	V-538	Clean demineralizers or water softeners
34	K-324	Remove or replace precipitators
35	K-327	Remove or replace steam or temperature recording equipment

TM #14

Title: OPERATING CENTRAL STEAM PLANTS

1	E-106	Make entries on AF Form 1458 (Daily Steam Boiler Plant Operating Log)
2	E-108	Make entries on AF Forms 1464 (Monthly Steam Boiler Plant Operating Log)
3	H-215	Analyze pressure or temperature readings
4	S-504	Isolate central steam plant boiler flame control malfunctions
5	S-505	Perform automatic boiler control operational checks
6	S-506	Perform central steam plant boiler draft control operational checks
7	S-507	Perform central steam plant boiler or expansion tank hydrostatic tests
8	S-512	Regulate steam output of boilers
9	T-520	Adjust central steam plant regulating valves
10	T-521	Blowdown central steam plant boiler or water columns
11	T-522	Check central steam plant boiler water level
12	T-526	Light-off central steam plant boilers
13	T-527	Monitor central steam plant electrostatic precipitators
14	T-528	Monitor central steam plant mechanical pollution collectors

TASK NUMBERTITLE

15	T-529	Monitor oil pre-heaters
16	T-530	Perform central steam plant boiler pre-operational checks
17	T-531	Perform central steam plant combustion efficiency analyses
18	T-532	Perform corrective action in case of boiler safety shutdowns
19	V-544	Monitor demineralizers or water softeners
20	V-547	Recharge demineralizers

TM #15

Title: MAINTAINING PNEUMATIC SYSTEMS

1	H-211	Adjust oil safety machines
2	H-220	Calibrate oil safety switches
3	H-235	Remove or replace oil safety switches
4	J-264	Adjust air compressor belts
5	J-265	Adjust air compressor pressure controls
6	J-266	Adjust pneumatic controls
7	J-267	Adjust pressure regulators
8	J-268	Align air compressor belts
9	J-269	Blowdown condensate from air tanks
10	J-270	Calibrate pneumatic controls
11	J-271	Clean and lubricate compressors
12	J-272	Inspect compressor oil levels
13	J-273	Isolate pneumatic control malfunctions
14	J-274	Perform pneumatic safety valve operational checks
15	J-275	Remove or replace pneumatic controls
16	J-276	Remove or replace pressure controls
17	K-290	Clean oil separators
18	K-322	Remove or replace oil separators

TM #16

Title: MAINTAINING HEATING ELECTRICAL SYSTEMS

1	I-241	Inspect electrical circuits
2	I-242	Inspect electrical power supplies
3	I-243	Inspect fuses or circuit breakers
4	I-248	Isolate electrical system malfunctions
5	I-249	Measure motor current draw
6	I-250	Remove or replace circuit breakers
7	I-251	Remove or replace electric motors
8	I-252	Remove or replace fuses
9	I-253	Remove or replace motor starters

TASK NUMBERTITLE

10	I-254	Remove or replace relays
11	I-255	Remove or replace starting or running capacitors
12	I-257	Remove or replace transformers
13	I-258	Reset circuit breakers
14	I-259	Reset motor thermal overloads
15	I-260	Test motor running or starting windings
16	I-261	Test starting or running capacitors
17	I-262	Test transformers
18	I-263	Wire-in motors to power sources

TM #17

Title: OPERATING STEAM HEATING SYSTEMS

1	N-418	Adjust demineralizers or water softeners
2	N-419	Adjust steam heating system deaerators
3	N-420	Adjust steam heating system feed water regulators
4	N-421	Adjust steam heating system steam regulating valves
5	N-422	Blowdown steam heating system boilers or water columns
6	N-423	Check steam heating system boiler tricocks
7	N-424	Light-off steam heating system boilers
8	N-425	Perform steam heating system boiler draft control operational checks
9	N-426	Perform steam heating system boiler pre-operational checks
10	N-427	Perform steam heating system combustion efficiency analyses

TM #18

Title: MAINTAINING STEAM HEATING SYSTEMS

1	G-197	Remove or replace boilers
2	G-203	Remove or replace sectional boiler sections
3	H-224	Inspect reheating systems
4	K-291	Clean strainers
5	K-312	Remove or replace check valves
6	K-313	Remove or replace chemical feeding equipment
7	M-361	Clean and inspect steam heating system combustion chambers
8	M-362	Clean and lubricate steam heating system steam indicating and recording equipment
9	M-363	Clean feed water controls (McDonnell-Miller)
10	M-364	Clean mud drums

TASK NUMBERTITLE

11	M-365	Clean new tube ends with emery cloth
12	M-366	Clean steam drums
13	M-367	Clean steam heating system boiler airflow switches
14	M-368	Clean heating system boiler gauge glasses
15	M-369	Clean steam heating system boiler tubes
16	M-370	Clean tube sheets
17	M-371	Cut tubes to prescribed length
18	M-372	Drain demineralizers or water softeners
19	M-373	Drain steam heating system boilers
20	M-374	Drain steam systems other than boilers
21	M-375	Fill steam heating system boilers
22	M-376	Inspect and clean steam heating system smokestacks
23	M-377	Inspect and wash down steam heating system boiler water sides
24	M-378	Inspect condensate lines or conduits
25	M-379	Inspect demineralizers or water softeners
26	M-380	Inspect feed water controls (McDonnell-Miller)
27	M-381	Inspect fire tubes for leaks or soot build-up
28	M-382	Inspect steam heating system boiler feed and condensate pumps
29	M-383	Inspect steam heating system boiler fusible plugs
30	M-384	Inspect steam heating system boiler manhole and handhole covers
31	M-385	Inspect steam heating system boiler safety valves
32	M-386	Inspect steam heating system combustion chambers
33	M-387	Inspect steam heating system deaerators
34	M-388	Inspect steam heating system expansion joints
35	M-389	Inspect steam heating system steam indicating and recording equipment
36	M-390	Inspect steam lines or conduits
37	M-391	Inspect steam traps
38	M-392	Inspect water tubes for leaks
39	M-393	Install new tubes by hand
40	M-394	Install new tubes with rolling device
41	M-395	Insulate low pressure steam heating system combustion chamber doors
42	M-396	Isolate steam heating system boiler flame control malfunctions
43	M-397	Perform demineralizer or water softener operational checks
44	M-398	Perform steam heating system refractory repairs
45	M-399	Rebuild feed water controls (McDonnell-Miller)

TASK NUMBERTITLE

46	M-400	Rebuild steam traps
47	M-402	Remove damaged tubes
48	M-403	Remove or replace black iron steam condensate lines
49	M-404	Remove or replace boiler fusible plugs
50	M-405	Remove or replace boiler safety valves
51	M-406	Remove or replace demineralizers or water softeners
52	M-407	Remove or replace feed water controls (McDonnell-Miller)
53	M-408	Remove or replace low pressure steam heating combustion chamber doors
54	M-409	Remove or replace steam heating system boiler gauge glasses
55	M-410	Remove or replace steam heating system boiler manhole or handhole over gaskets
56	M-411	Remove or replace steam heating system boiler feed or condensate pumps
57	M-412	Remove or replace steam heating system deaerators
58	M-413	Remove or replace steam heating system pressure relief valves
59	M-314	Remove or replace steam heating system safety valves
60	M-315	Remove or replace steam heating system valves or fittings other than safety or pressure relief
61	M-316	Remove or replace thermosetting resin pipe
62	M-417	Trace steam distribution systems

TM #19

Title: OPERATING FUEL BURNING EQUIPMENT AND AREA

1	232. L-334	Adjust gas burner fuel-air ratios
2	233. L-335	Adjust oil burner fuel-air ratios
3	234. L-336	Adjust oil pre-heaters
4	L-337	Inspect ash-handling equipment
5	L-351	Perform gas burner operational checks
6	L-353	Perform oil burner operational checks
7	L-355	Perform solid fuel burner operational checks
8	W-572	Read meters
9	W-576	Remove or replace interior gas service lines

TM #20

TASK NUMBERTITLE

Title: MAINTAINING FUEL BURNING EQUIPMENT AND AREA

1	G-198	Remove or replace coal burning equipment
2	L-339	Inspect fuel lines or fittings
3	L-340	Inspect gas burners
4	L-341	Inspect liquid petroleum tanks
5	L-342	Inspect oil burners
6	L-343	Inspect oil pre-heaters
7	L-344	Inspect oil storage tanks
8	L-345	Inspect oil tanks for water or other impurities
9	L-346	Inspect solid fuel burners
10	L-347	Lubricate gas burners
11	L-348	Lubricate oil burners
12	L-349	Lubricate solid fuel burners
13	L-350	Perform ash-handling equipment preventive maintenance
14	L-352	Perform liquid petroleum tank preventive maintenance
15	L-354	Perform oil storage tank preventive maintenance
16	L-356	Remove or replace gas burners
17	L-357	Remove or replace oil burners
18	L-358	Remove or replace oil pre-heaters
19	L-359	Remove or replace solid fuel burners
20	L-360	Verify quantity of fuel oil in tank
21	U-533	Collect coal samples of analyses
22	U-534	Inspect coal handling equipment
23	U-535	Inspect coal shipments
24	U-536	Maintain coal storage areas
25	U-537	Prepare coal samples for analyses